FG No. 3

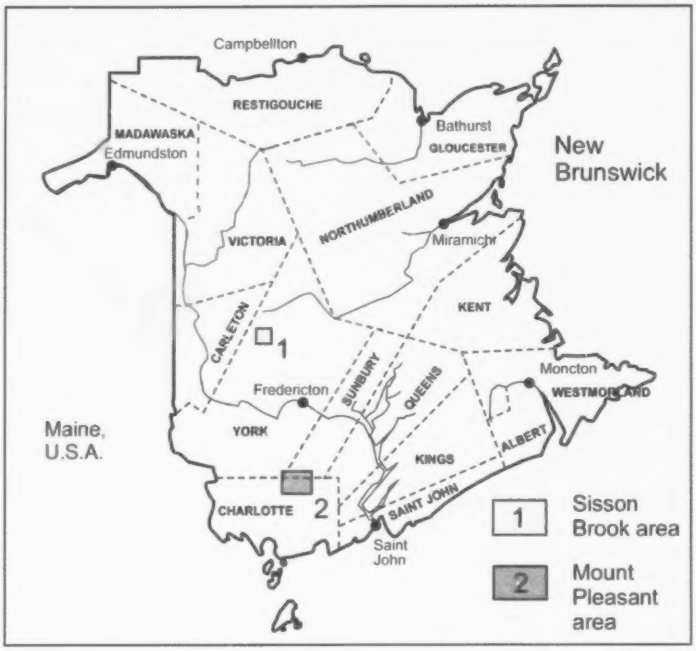
Field Guide

New Nouveau Brunswick
Natural Resources
Lands, Minerals and Petroleum

POLYMETALLIC DEPOSITS OF SISSON BROOK AND MOUNT PLEASANT, NEW BRUNSWICK, CANADA

L.R. Fyffe and K.G. Thorne (compilers)

2010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New Brunswick
NORTHUMBERLAND
VICTORIA
Miramichi
KENT
CARLETON
1
Fredericton
SUNBURY
QUEENS
Moncton
WESTMORLAND
Maine, U.S.A.
YORK
KINGS
ALBERT
CHARLOTTE
2
SAINT JOHN
Saint John
1 Sisson Brook area
2 Mount Pleasant area

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Print Edition
ISBN 978-1-55471-026-3

Online Edition
ISBN 978-1-55471-027-0

CD-ROM Edition
ISBN 978-1-55471-028-7

Cover illustration	Sisson Brook polymetallic deposit in west-central New Brunswick, looking northwest. View shows Sisson Brook in foreground, Zone III trench in upper right, and knoll underlain by the Nashwaak Granite in upper right background. *Photograph courtesy of D.J.J. Carroll*
Figure preparation	Terry Leonard
Editing, design, layout	Gwen L. Martin
Translation	Le Bureau de traduction, Ministère de l'Approvisionnement et des Services du Nouveau-Brunswick (Translation Bureau, New Brunswick Department of Supply and Services)
Recommended citation	Fyffe, L.R., and Thorne, K.G. (compilers). 2010. Polymetallic deposits of Sisson Brook and Mount Pleasant, New Brunswick, Canada. New Brunswick Department of Natural Resources; Lands, Minerals and Petroleum Division, Field Guide No. 3, 68 p.

This report has been prepared by:

Lands, Minerals and Petroleum Division
New Brunswick Department of Natural Resources

Hon. Wally Stiles
Minister of Natural Resources

July 2010

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ACKNOWLEDGEMENTS

The compilers would like to thank the staff members of Geodex Minerals Ltd. and Adex Mining Inc. for their assistance with the original field trip and field guide preparation, and for allowing access to their properties and information. Also, thanks to Terry Leonard for her assistance in drafting the field guide figures.

Note

Descriptions of the Sisson Brook and Mount Pleasant deposits and field trip stops provided in this guidebook are modified and updated from Thorne (2009), a field guide prepared for the 2009 International Applied Geochemistry Symposium held in Fredericton, New Brunswick.

ABSTRACT

This field guide describes two granite-related polymetallic mineral deposits that have been extensively explored in New Brunswick, Canada. One is located at Sisson Brook in west-central New Brunswick and is a large-tonnage, low-grade tungsten–molybdenum–copper deposit. The other is situated at Mount Pleasant in southwestern New Brunswick and is a small-tonnage, high-grade tin–tungsten–molybdenum–bismuth–indium deposit. Both deposits are associated with similarly aged plutonic rocks but exhibit contrasting mineralization styles that reflect different physicochemical conditions of formation. The geological settings and mineralization styles at Sisson Brook and Mount Pleasant can be observed in road, power line, quarry, and trench exposures. Metallogenetic models developed for these two deposits are compared here with those proposed for other polymetallic deposits in the region.

RESUMÉ

Le présent guide d'excursion renferme la description de deux gîtes de minéraux polymétalliques granitiques dont on a fait la prospection de façon intensive au Nouveau-Brunswick (Canada). Le premier, situé à Sisson Brook, dans le centre ouest du Nouveau-Brunswick, est un gîte à tonnage important et à faible teneur en tungstène, en molybdène et en cuivre. Le deuxième, situé au mont Pleasant, dans le sud-ouest de la province, est un gîte à tonnage faible et à haute teneur en étain, en tungstène, en molybdène, en bismuth et en indium. Les deux gîtes sont associés à des roches plutoniques du même âge mais présentent des styles de minéralisation opposés qui montrent des conditions physicochimiques de formations différentes. Le cadre géologique et les styles de minéralisation à Sisson Brook et au mont Pleasant peuvent être observés dans des affleurements causés par des routes, des lignes de transport d'électricité, des carrières et des tranchées. Les modèles métallogéniques élaborés pour ces deux gîtes sont comparés à ceux élaborés pour les autres gîtes polymétalliques de la région.

INTRODUCTION

POLYMETALLIC DEPOSITS

Polymetallic mineral deposits within intraplate continental settings are typically associated with late-stage, highly evolved granitic magmas enriched in lithophile elements such as silica, rubidium, lithium, beryllium, boron, and fluorine. The occurrence of these granite-related polymetallic mineral deposits in post-tectonic, intraplate settings can be attributed to the existence of a continental crust thickened by previous orogenesis. Extension of this thickened crust can lead to underplating by mafic magma and to the production of large volumes of granitic melt in upper crustal magma chambers. Volatiles, including fluorine, emanating from the underplated mafic magmas can infiltrate the granitic melts and become further enriched in small volumes of melt through the fractionation process (Carten et al. 1993).

The presence of a fluxing agent such as fluorine in a silicate melt is particularly significant in the formation of polymetallic mineral deposits in that it lowers the crystallization temperature and allows the melt more time to evolve and rise higher into the crust. During this evolutionary process, metals such as tungsten, molybdenum, and tin become concentrated in the late-stage melts and in hydrothermal fluids. These metals may be deposited as disseminations, breccia fillings, stockwork veinlets, and massive quartz-vein systems along the contact of, and in the apical portions of, high-level plutons following quenching of the silica-rich melt due to release of fluid pressure (Strong 1981).

This field guide presents two granite-related polymetallic mineral deposits that have been extensively explored in New Brunswick. *Part 1* describes the large-tonnage, low-grade tungsten–molybdenum–copper deposit at Sisson Brook in west-central New Brunswick. *Part 2* examines the small-tonnage, high-grade tin–tungsten–molybdenum–bismuth–indium deposit at Mount Pleasant in southwestern New Brunswick. These two deposits are associated with similarly aged plutonic rocks but exhibit contrasting styles of mineralization that reflect the different physicochemical conditions under which the mineralizing processes occurred.

GEOLOGICAL OVERVIEW

The following section summarizes the regional geology of west-central and southwestern New Brunswick to provide a geological context for the Sisson Brook and Mount Pleasant deposits.

Basement rocks of Precambrian to earliest Cambrian age underlie the southeastern corner of the report area (Fig. 1) and are separated into two parts by a belt of Early Silurian mainly felsic volcanic rocks of the Kingston Group. Mesoproterozoic to Neoproterozoic basement rocks of the **Green Head Group** underlie the area to the southeast of the Early Silurian Kingston Group. The Green Head Group comprises stromatolitic marble and lesser quartzose sandstone (Ashburn Formation) and overlying siltstone, quartzose sandstone, quartzite-

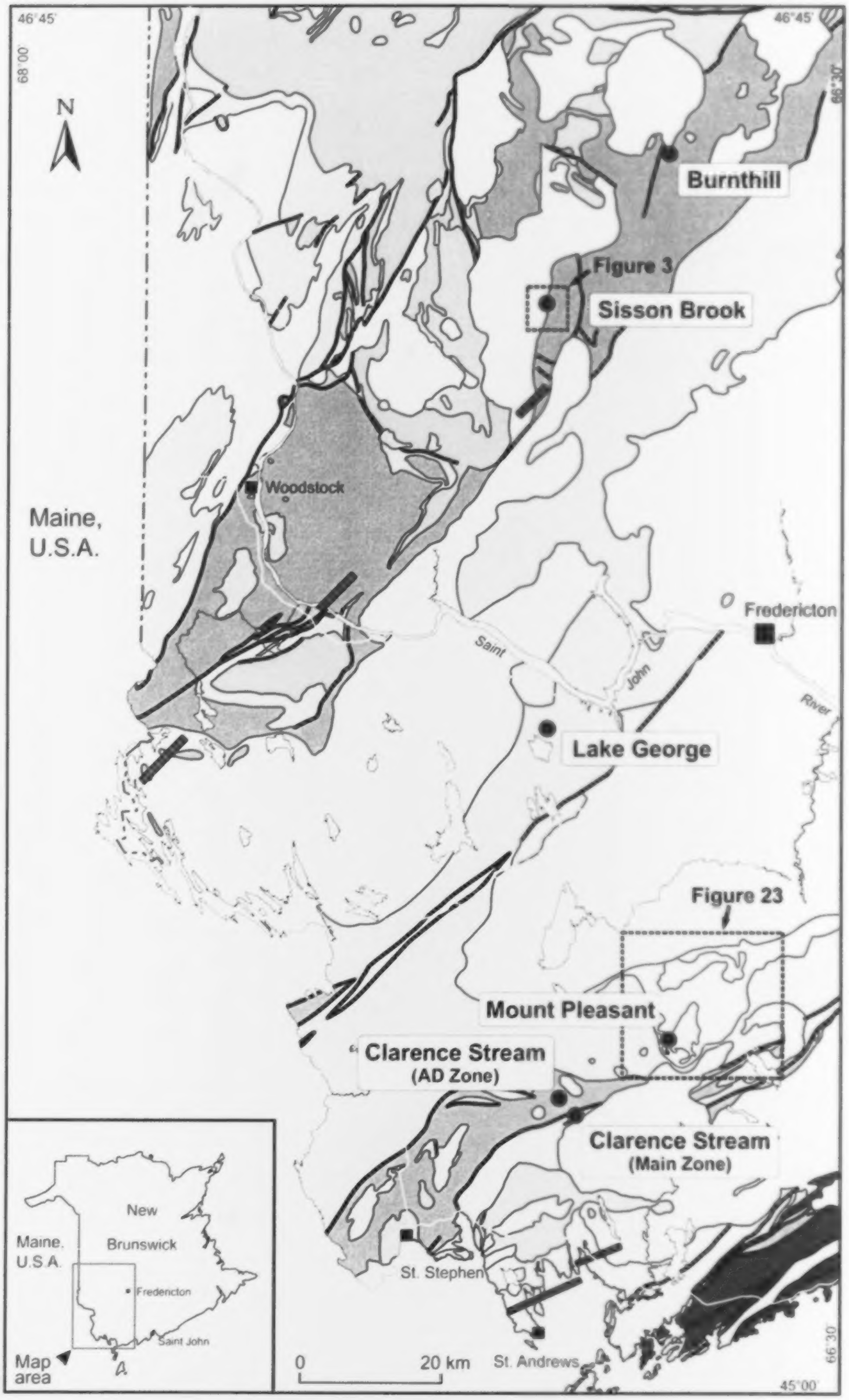
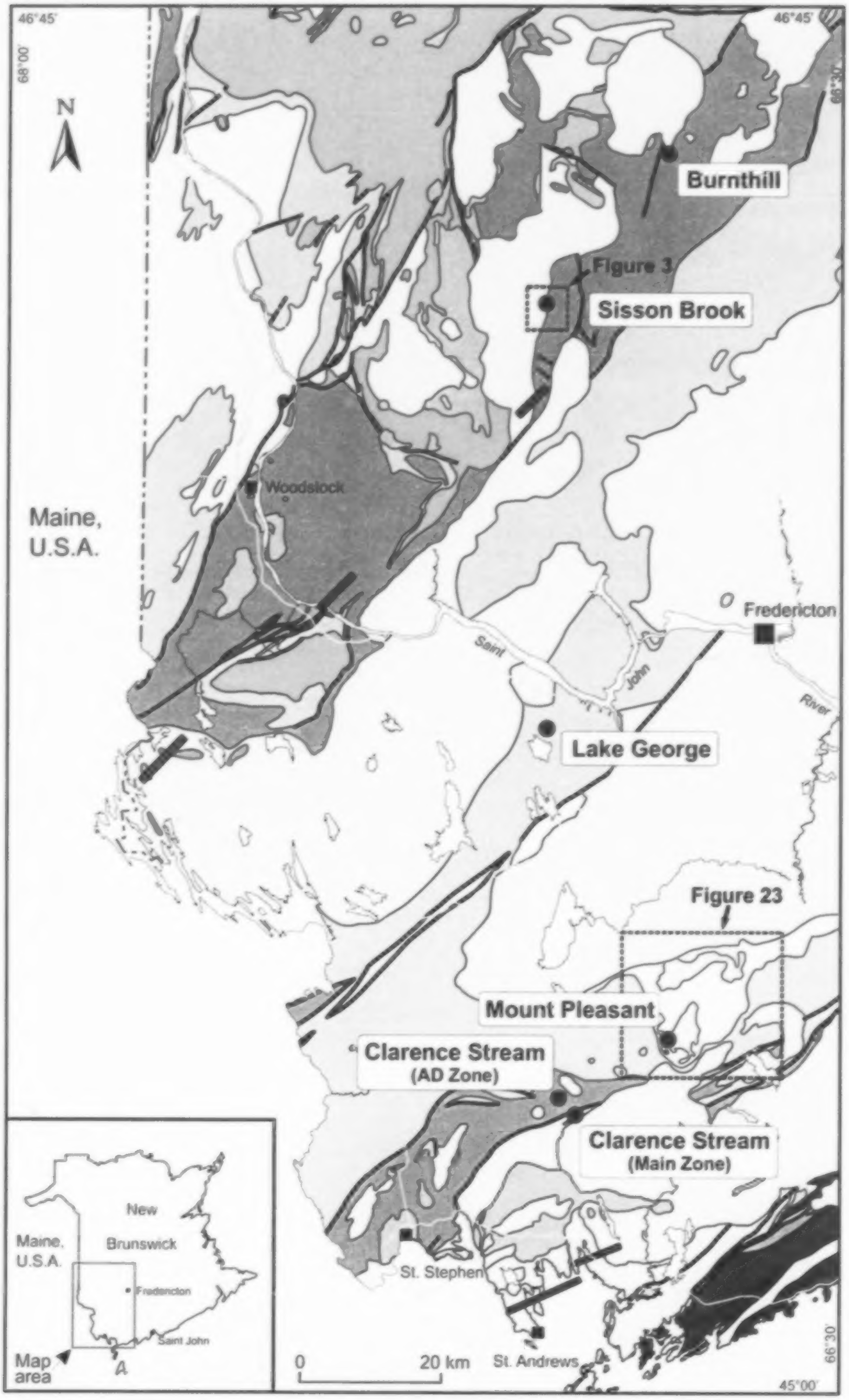

46°45'
68°00'
N
46°45'
66°30'
Burnthill
Figure 3
Sisson Brook
Woodstock
Maine,
U.S.A.
Fredericton
Saint
John
River
Lake George
Figure 23
Mount Pleasant
Clarence Stream
(AD Zone)
Clarence Stream
(Main Zone)
St. Stephen
St. Andrews
0
20 km
66°30'
45°00'
New
Brunswick
Maine,
U.S.A.
Fredericton
Saint John
Map
area

Figure 1. Geology of west-central and southwestern New Brunswick, showing the Sisson Brook and Mount Pleasant polymetallic deposits, as well as other major deposits noted in the text (legend on facing page). Geology is after Smith (2006) and Smith and Fyffe (2006).


46°45'
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Burnthill
Figure 3
Sisson Brook
Woodstock
Maine,
U.S.A.
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Mount Pleasant
Clarence Stream
(AD Zone)
Clarence Stream
(Main Zone)
St. Stephen
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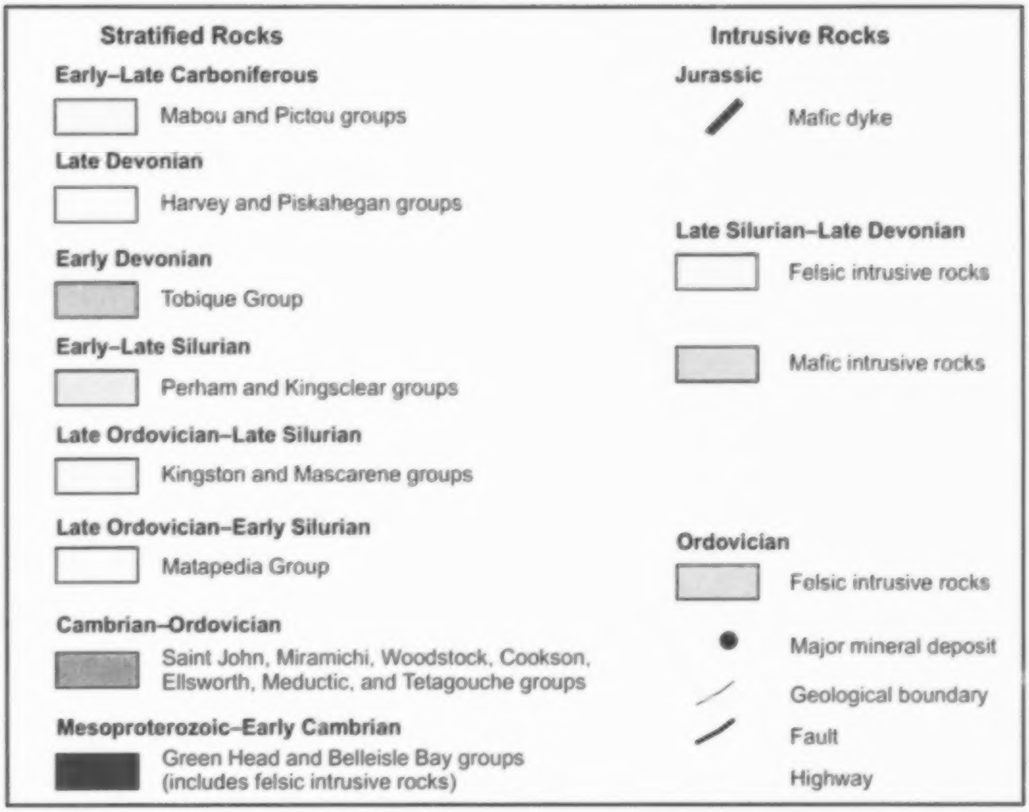
Stratified Rocks
Early–Late Carboniferous
Mabou and Pictou groups
Late Devonian
Harvey and Piskahegan groups
Early Devonian
Tobique Group
Early–Late Silurian
Perham and Kingsclear groups
Late Ordovician–Late Silurian
Kingston and Mascarene groups
Late Ordovician–Early Silurian
Matapedia Group
Cambrian–Ordovician
Saint John, Miramichi, Woodstock, Cookson, Ellsworth, Meductic, and Tetagouche groups
Mesoproterozoic–Early Cambrian
Green Head and Belleisle Bay groups (includes felsic intrusive rocks)
Intrusive Rocks
Jurassic
Mafic dyke
Late Silurian–Late Devonian
Felsic intrusive rocks
Mafic intrusive rocks
Ordovician
Felsic intrusive rocks
Major mineral deposit
Geological boundary
Fault
Highway

Figure 1 *(cont'd)*. Legend for map on facing page.

pebble conglomerate, and marble breccia (Martinon Formation) (Alcock 1938; Leavitt 1963; Hofmann 1974; Currie 1991). The Green Head Group is intruded by a suite of plutonic rocks that range from Neoproterozoic to Early Cambrian (~555 to ~528 Ma) and that possess mainly calc-alkaline, continental margin geochemical signatures (Eby and Currie 1996; White and Barr 1996; Currie and McNicoll 1999; White et al. 2002; Barr et al. 2003).

Basement rocks to the northwest of the Early Silurian Kingston Group include the Blacks Harbour Granite dated at ~622 Ma (Barr et al. 2003; Bartsch and Barr 2005) and the Ragged Falls Granite dated at ~553 Ma (Currie and Hunt 1991; Johnson and McLeod 1996; Johnson 2001; McLeod et al. 2003.) Minor felsic volcanic rocks (Leavitts Head Formation) of the Belleisle Bay Group are preserved as roof pendants in the Ragged Falls Granite and have been dated at ~549 Ma (McLeod et al. 2003). A sequence of felsic and mafic volcanic rocks and arkosic sandstone (Simpsons Island Formation) of the Belleisle Bay Group lies along the faulted northwestern flank of the Blacks Harbour Granite (McLeod 1995; Johnson and McLeod 1996; Johnson 2001; McLeod et al. 2001). This sequence has been dated at ~539 Ma or earliest Cambrian (Barr et al. 2003; Bartsch and Barr 2005).

Interbedded shallow-water sedimentary and volcanic rocks of the Cambrian Saint John Group along Buckmans Creek are faulted against the Blacks Harbour Granite. The Saint John Group in this area comprises a lower section of conglomerate and quartzose sandstone; a middle section of basaltic volcanic rocks, red siltstone and minor limestone;

and an upper section of limestone and pyritiferous shale (Greenough et al. 1985; Johnson 2001). Early to Middle Cambrian trilobites occur in limestone beds in the middle and upper sections (Helmstaedt 1968; Landing et al. 2008). The basaltic volcanic rocks have an evolved, continental tholeiitic geochemical signature (Greenough et al. 1985).

Deeper water Cambrian volcanic and sedimentary sequences along the northwestern flank of the Ragged Falls Granite are included in the **Ellsworth Group** in New Brunswick, as they are similar in age and geological setting to the Ellsworth Schist in adjacent Maine (Schultz et al. 2008; Fyffe et al. 2009). Iron-rich volcaniclastic sandstone interbedded with felsic flows and tuff (Mosquito Lake Road Formation) have been dated at ~514 Ma, indicating a late Early Cambrian age (Ruitenberg et al. 1993; Johnson and McLeod 1996; Johnson 2001; McLeod et al. 2003). The volcanic-rich sequence is underlain by quartzose sandstone and intraformational quartzite-pebble conglomerate (Matthews Lake Formation). The mafic volcanic rocks of the Mosquito Lake Road Formation possess a volcanic-arc geochemical signature (Johnson and McLeod 1996).

The **Cookson Group** comprises a thick sequence of Late Cambrian to Middle Ordovician clastic sandstone and shale (Ruitenberg 1967; Ludman 1987, 1991; Fyffe and Riva 1990) that is separated from Precambrian to earliest Cambrian basement rocks to the south by the Late Ordovician to Late Silurian Mascarene Group. Thick-bedded quartzose sandstone containing pods of pink garnet (Crocker Hill Formation) forms the base of the Cookson sequence and correlates with the Megunticook Formation in the Penobscot Bay area of Maine (Tucker et al. 2001). Overlying carbonaceous shale intercalated with minor thin beds of silty sandstone (Calais Formation) contains a pillow basalt unit just above the contact with the Crocker Hill Formation. The pillow basalt has an evolved, mid-oceanic-ridge tholeiitic geochemical signature (Fyffe et al. 1988a). Graptolites found on Cookson Island in Oak Bay indicate that the Calais Formation is as young as Tremadocian (Early Ordovician) (Fyffe and Riva 1990). A U–Pb date of ~503 Ma on a tuff bed in the equivalent Penobscot Formation in Maine suggests that the deposition of black shale began as early as the Middle Cambrian (Tucker et al. 2001). Thin- to medium-bedded feldspathic wacke interbedded with siltstone and shale (Woodland Formation) overlies the Calais Formation. The Woodland Formation in turn is overlain by thick-bedded quartzose sandstone interbedded with carbonaceous shale and minor quartz-pebble conglomerate (Kendall Mountain Formation). Graptolites from the Kendall Mountain shale indicate a Caradocian (Middle Ordovician) age (Fyffe and Riva 1990).

Interbedded sedimentary and volcanic rocks of the Late Ordovician to Late Silurian **Mascarene Group** include the Oak Bay, Waweig, Eastport, Letete, Back Bay, and Goss Point formations (Donohoe 1973; Johnson and McLeod 1996; Fyffe et al. 1999; McLeod et al. 2001; Miller and Fyffe 2002; Van Wagoner et al. 2002). Early Silurian conglomerate of the Oak Bay Formation at the base of the Mascarene Group lies with faulted angular unconformity on polydeformed black shale (Calais Formation) along the southeastern flank of the Cookson Group (Gates 1969). The conglomerate contains clasts of black shale of clearly local origin but also contains abundant igneous clasts of Neoproterozoic age that were derived from a more distal source (Fyffe et al. 2009). Felsic tuffs in the Waweig and Letete formations have been dated as Early Silurian (~438 Ma) and in the Eastport Formation as Late Silurian (~423 Ma) (Van Wagoner et al. 2001; Miller and Fyffe 2002).

The **Kingston Group**, which separates basement rocks of the Green Head Group from those of the Belleisle Bay Group, is dated at ~442 Ma (Barr et al. 2002). Fyffe et al. (1999) and Barr et al. (2002) proposed that the Kingston Group and related granitic plutons and younger mafic dykes represent an extensional volcanic arc formed during subduction of an oceanic tract in the Early Silurian.

Early Silurian feldspathic wacke and shale (Digdeguash Formation) at the base of the **Kingsclear Group** lie concordantly on Ordovician quartzose sandstone and shale (Kendall Mountain Formation) along most of the northwestern flank of the Cookson Group (Ruitenberg 1967; Fyffe and Riva 1990, 2001; Fyffe et al. 1999). Calcareous sandstone and shale (Sand Brook and Flume Ridge formations) conformably overlie the Digdeguash Formation. A fault marks the contact of the Silurian Kingsclear Group with the Cambrian to Middle Ordovician sedimentary and volcanic rocks of the Miramichi Highlands to the northwest (Fyffe 1995).

The Miramichi Highlands of central and northeastern New Brunswick (Fig. 2) are characterized by Cambrian to Early Ordovician quartzose sedimentary rocks of the **Miramichi Group** and overlying Middle Ordovician volcanic rocks of the **Tetagouche Group** (van Staal and Fyffe 1991, 1995a, 1995b; van Staal et al. 1992; Fyffe et al. 1997). The Miramichi Group is divided into a lower sequence of thick-bedded quartzose sandstone (Chain of Rocks Formation), a middle sequence of medium-bedded quartzose sandstone and shale (Knights Brook Formation), and an upper sequence of medium-bedded feldspathic wacke and shale (Patrick Brook Formation).

The base of the Tetagouche Group in the central Miramichi Highlands is marked by a thin unit of conglomerate and interbedded calcareous siltstone and felsic tuff (Turnbull Mountain Formation) that lies unconformably on wacke beds of the Patrick Brook Formation. The calcareous siltstone in the Turnbull Mountain Formation in central New Brunswick and correlative Vallée Lourdes Formation in the Bathurst area of northeastern New Brunswick contain Early Ordovician (Arenigian) brachiopods of the Celtic biogeographic province (Fyffe 1976; Neuman 1984; Fyffe et al. 1997; Poole and Neuman 2003). The upper part of the Tetagouche Group in central New Brunswick comprises a sequence of ferromanganiferous cherty siltstone, and black chert and shale interbedded with mafic volcanic rocks (Hayden Lake Formation); and an overlying sequence of wacke and shale (Push and Be Damned Formation). The bimodal volcanic rocks of the Tetagouche Group are interpreted, on the basis of their geochemical composition, to have been generated in an intra-arc rift to back-arc basin transitional setting (van Staal 1987; van Staal et al. 1991, 2003; van Staal and Fyffe 1995a).

The southwestern portion of the Miramichi Highlands near Woodstock is underlain by quartz-rich sedimentary and volcanic sequences referred to as the Woodstock and Meductic groups, respectively (Fyffe 2001). The **Woodstock Group** includes a thick sequence of quartzose sandstone and shale (Baskahegan Lake Formation) and conformably overlying carbonaceous shale (Bright Eye Brook Formation). Trace fossils recovered near Woodstock suggest that the

Baskahegan Lake Formation may be as young as Early Ordovician (Pickerill and Fyffe 1999). Graptolites from the Bright Eye Brook Formation indicate an Early Ordovician (Tremadocian–early Arenigian) age (Fyffe et al. 1983).

The conformably overlying **Meductic Group** is divided into three volcanic units: a lower sequence of felsic volcanic flows and tuff (Porten Road Formation), a middle sequence of intermediate tuff and volcaniclastic rocks (Eel River Formation), and an upper sequence of mafic volcanic flows and tuff (Oak Mountain Formation). Graptolites from overlying wacke and shale (Belle Lake Formation) indicate a Middle Ordovician (early Caradocian) age (Fyffe et al. 1983). The Benton pluton, which is comagmatic with volcanic rocks of the Meductic Group, is dated at ~479 Ma (Whalen et al. 1998). This indicates that volcanic activity in the Woodstock area began before volcanism of the Tetagouche Group (~474 Ma to ~457 Ma) in the Bathurst area farther northeast. The Meductic volcanic rocks have an arc geochemical signature and thus are interpreted to represent a volcanic arc that developed just prior to opening of the Tetagouche back-arc basin (Dostal 1989; van Staal and Fyffe 1995b; Fyffe 2001).

Abundant plutonic rocks ranging from Late Silurian to Late Devonian and from gabbro to granite intrude the highly deformed Cambrian to Ordovician rocks of the Miramichi Highlands (Fig. 2) (Fyffe et al. 1981; Bevier and Whalen 1990; Whalen 1993; Whalen et al. 1996). The Sisson Brook polymetallic deposit is located along the margin of one of these plutons in west-central New Brunswick (Fig. 1).

In western New Brunswick, the oldest rocks exposed northwest of the Miramichi Highlands are of the Late Ordovician to Early Silurian (Ashgillian–Llandoverian) **Matapedia Group**. These rocks consist of thin-bedded, very fine-grained argillaceous limestone rhythmically interbedded with calcareous shale (White Head Formation). The White Head Formation is conformably overlain by ferromanganiferous shale and thick-bedded calcareous sandstone, massive limestone, polymictic conglomerate, and graptolitic siltstone (Smyrna Mills Formation) of the Early to Late Silurian **Perham Group**. The Perham Group is conformably overlain by a sequence of interbedded mafic volcanic rocks, quartzose and lithic sandstone, siltstone, and shale (Wapske Formation); and felsic volcanic flows and tuffs (Costigan Mountain Formation) of the Early Devonian **Tobique Group** (Pavlides 1968; Hamilton-Smith 1972; St. Peter 1982; Wilson et al. 2004).

Essentially flat-lying Late Devonian to Carboniferous strata of the New Brunswick Platform overlie deformed Silurian sedimentary rocks of the Kingsclear Group with profound unconformity (Fig. 1). Late Devonian subaerial, mainly felsic, volcanic flows and tuffs of the **Harvey** and **Piskahegan groups** are exposed along the southwestern edge of the platform. The volcanic rocks are overlain by Late Mississippian red conglomerates (Shin Formation) of the **Mabou Group**, which in turn are overstepped by Pennsylvanian grey conglomerate and sandstone (Minto Formation) of the **Pictou Group** (van de Poll 1967; Fyffe and Barr 1986; McGregor and McCutcheon 1988; McCutcheon et al. 1997; St. Peter and Johnson 2009). The polymetallic Mount Pleasant deposit is associated with Late Devonian subvolcanic granitic rocks intruded into volcanic rocks of the Piskahegan Group.

PART 1: SISSON BROOK W–MO–CU DEPOSIT

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INTRODUCTION

The Sisson Brook tungsten–molybdenum–copper deposit is located in the Coldstream map area (NTS 21 J/06) of west-central New Brunswick, approximately 60 km northwest of Fredericton. As with many polymetallic deposits, the mineralization at Sisson Brook is closely associated with felsic igneous rocks. In this case, they comprise an extensive belt of plutonic rocks that crosses New Brunswick from southwest to northeast (Fig. 2). The Sisson Brook deposit was discovered by diamond drilling in 1979 and is divided into three mineralized zones: Zones I and II, which contain mainly wolframite and chalcopyrite; and Zone III, in which scheelite and molybdenite are predominant (Fig. 3). Since acquiring the property in 2004, Geodex Minerals Ltd. has conducted extensive exploration and assessment work (Martin 2006) and has undergone a pre-feasibility study to assess whether mine development should proceed (Ozturk 2007).

This part of the field guide describes road and trench exposures in the Sisson Brook area. The exposures are reviewed in the context of 1) the geological setting and mineralization style at Sisson Brook, 2) glacial deposits that overlie the deposit, 3) comparisons of the Sisson Brook deposit with selected other polymetallic deposits in New Brunswick, and 4) a possible genetic model based on the unique structural characteristics of the Sisson Brook deposit.

GEOLOGICAL SETTING

The Sisson Brook deposit is situated along the eastern margin of an extensive belt of Late Silurian to Early Devonian ("Acadian") plutonic rocks (Fig. 2) that underlie the Miramichi Highlands. The plutonic rocks were emplaced into a variety of country rocks, including sedimentary rocks of the Cambrian to Early Ordovician Miramichi Group; volcanic and sedimentary rocks of the Ordovician Tetagouche Group; and deformed Ordovician plutonic rocks (Fyffe 1982a, 1982b; van Staal and Fyffe 1991). The two Acadian plutons in the immediate vicinity of the Sisson Brook deposit (Fig. 3) are referred to as the Howard Peak Granodiorite and Nashwaak Granite (Fyffe et al. 1981).

Country Rocks

The country rocks immediately adjacent to the Howard Peak and Nashwaak plutons are an intercalated sequence of fine- to medium-grained, medium- to thick-bedded, light grey crystal

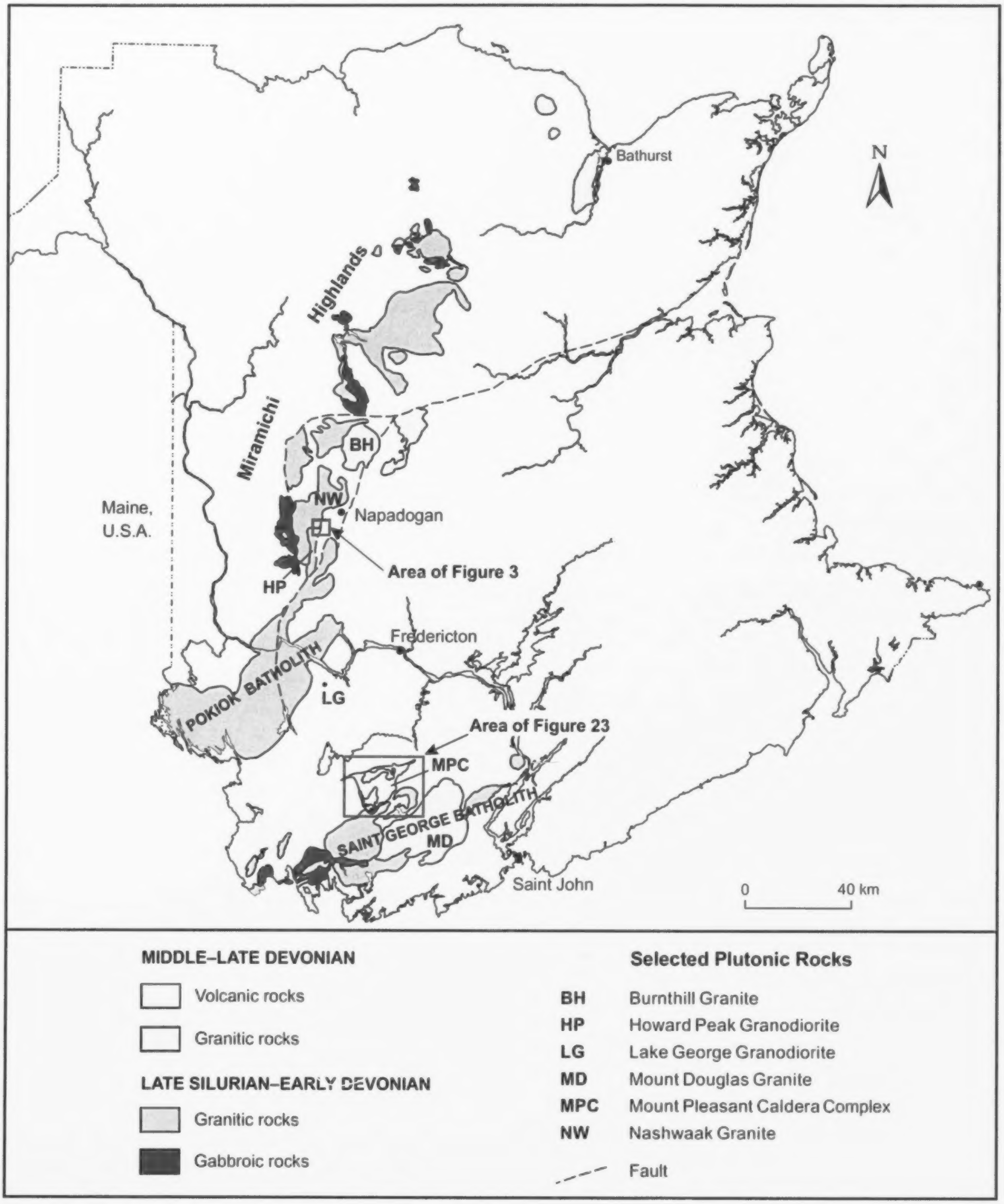
Bathurst
N
Highlands
Miramichi
BH
NW
Napadogan
Maine,
U.S.A.
Area of Figure 3
HP
Fredericton
POKIOK BATHOLITH
LG
Area of Figure 23
MPC
SAINT GEORGE BATHOLITH
MD
Saint John
0
40 km
MIDDLE–LATE DEVONIAN
Volcanic rocks
Granitic rocks
LATE SILURIAN–EARLY DEVONIAN
Granitic rocks
Gabbroic rocks
Selected Plutonic Rocks
BH Burnthill Granite
HP Howard Peak Granodiorite
LG Lake George Granodiorite
MD Mount Douglas Granite
MPC Mount Pleasant Caldera Complex
NW Nashwaak Granite
Fault

Figure 2. Geology map of New Brunswick, showing location of selected Late Silurian to Late Devonian plutonic rocks (from Fyffe et al. 2008), and of Figures 3 and 23.

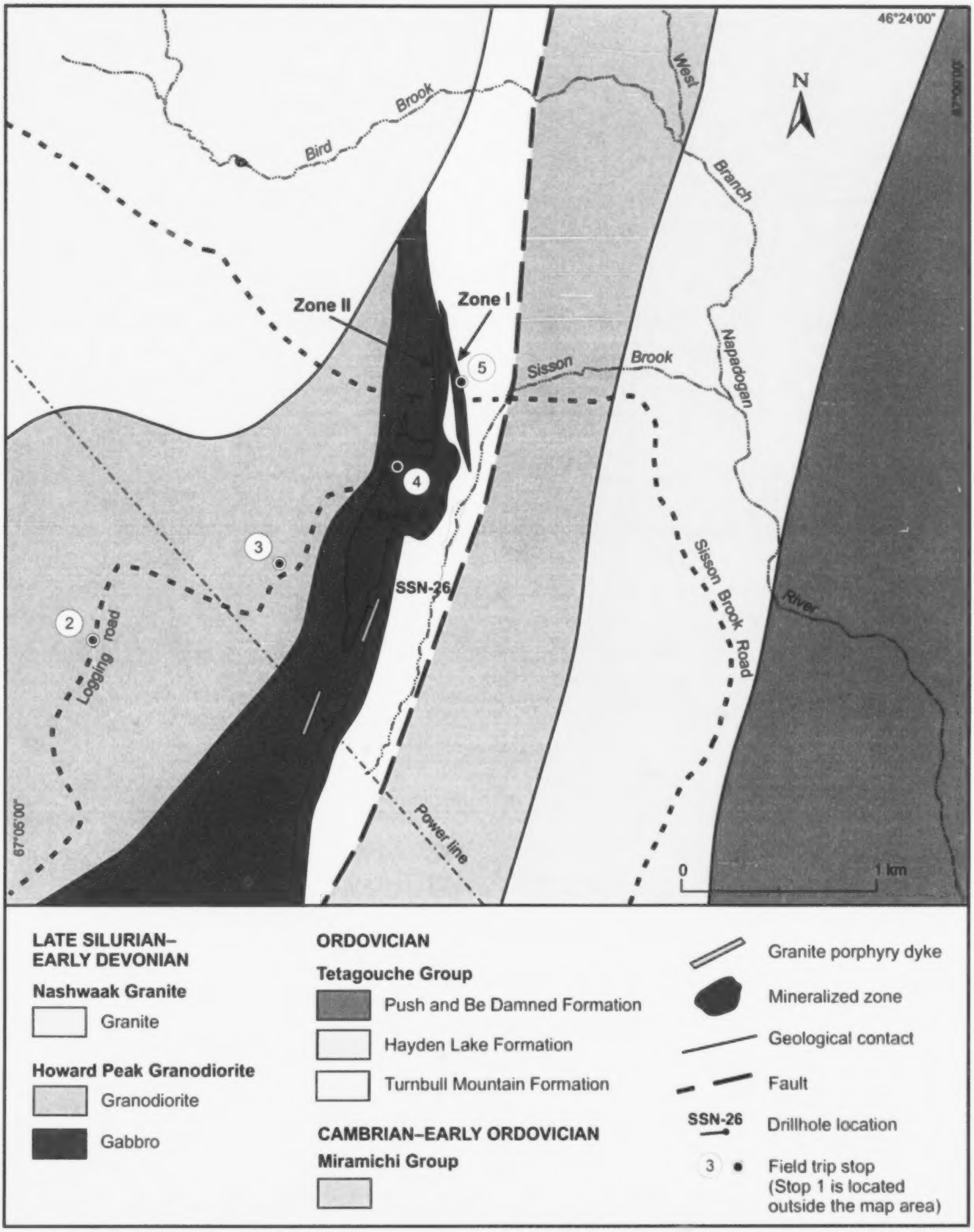
46°24'00"
67°00'00"
67°05'00"
N
Bird Brook
West Branch
Napadogan River
Sisson Brook
Zone II
Zone I
5
4
3
2
SSN-26
Logging road
Sisson Brook Road
Power line
0
1 km
LATE SILURIAN–EARLY DEVONIAN
Nashwaak Granite
Granite
Howard Peak Granodiorite
Granodiorite
Gabbro
ORDOVICIAN
Tetagouche Group
Push and Be Damned Formation
Hayden Lake Formation
Turnbull Mountain Formation
CAMBRIAN–EARLY ORDOVICIAN
Miramichi Group
Granite porphyry dyke
Mineralized zone
Geological contact
Fault
SSN-26 Drillhole location
3 Field trip stop
(Stop 1 is located outside the map area)

Figure 3. Geology map of the Sisson Brook area in west-central New Brunswick (from Fyffe et al. 2008). Figures 1 and 2 show location of this map area.

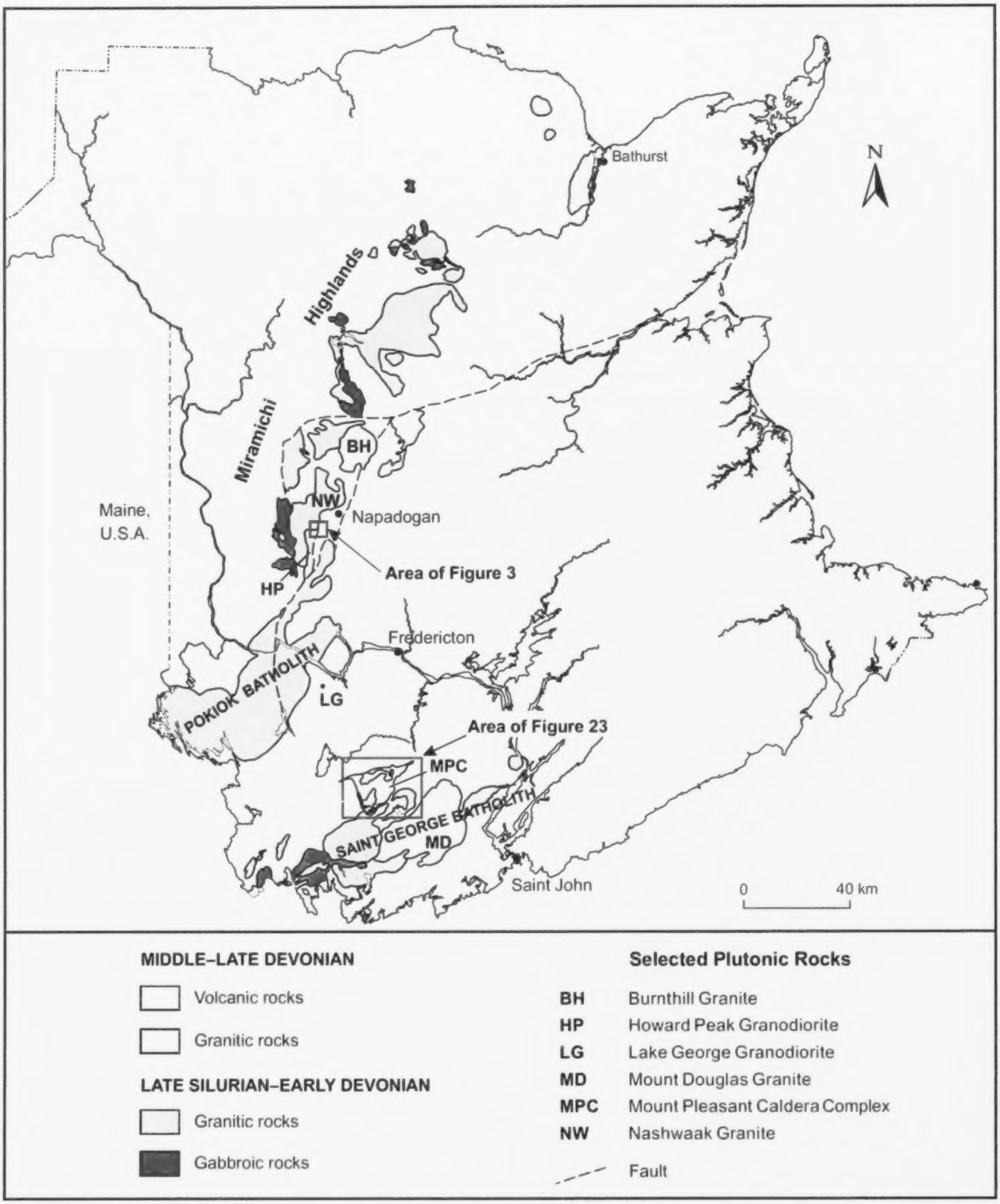
Bathurst
N
Highlands
Miramichi
BH
NW
Napadogan
Maine,
U.S.A.
Area of Figure 3
HP
Fredericton
POKIOK BATHOLITH
LG
Area of Figure 23
MPC
SAINT GEORGE BATHOLITH
MD
Saint John
0
40 km
MIDDLE–LATE DEVONIAN
Volcanic rocks
Granitic rocks
LATE SILURIAN–EARLY DEVONIAN
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Figure 2. Geology map of New Brunswick, showing location of selected Late Silurian to Late Devonian plutonic rocks (from Fyffe et al. 2008), and of Figures 3 and 23.

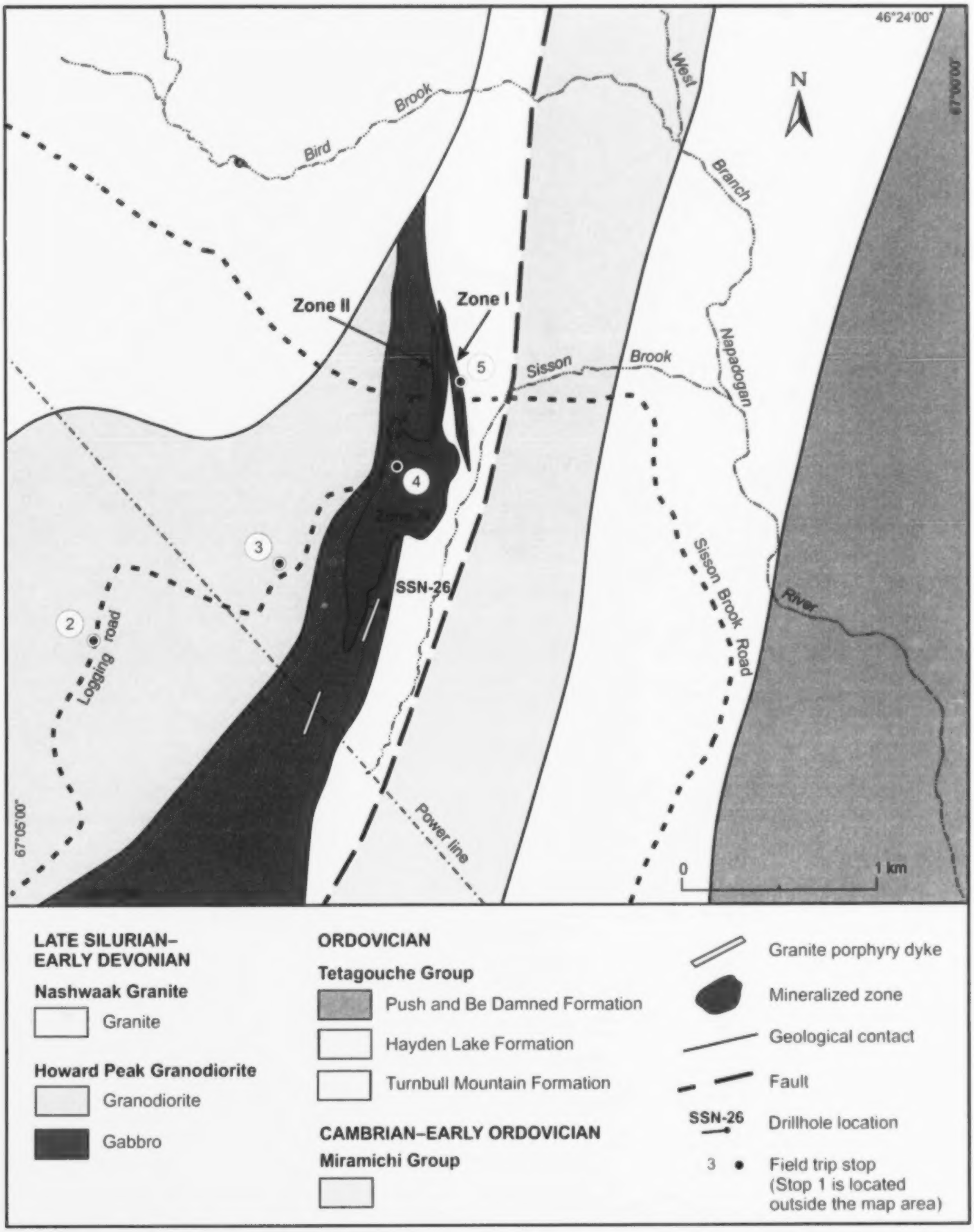
46°24'00"
67°00'00"
67°05'00"
N
West
Branch
Bird
Brook
Zone II
Zone I
Zone III
Sisson
Brook
Napadogan
River
Sisson Brook Road
SSN-26
Logging road
Power line
2
3
4
5
0
1 km
LATE SILURIAN–EARLY DEVONIAN
Nashwaak Granite
Granite
Howard Peak Granodiorite
Granodiorite
Gabbro
ORDOVICIAN
Tetagouche Group
Push and Be Damned Formation
Hayden Lake Formation
Turnbull Mountain Formation
CAMBRIAN–EARLY ORDOVICIAN
Miramichi Group
Granite porphyry dyke
Mineralized zone
Geological contact
Fault
SSN-26
Drillhole location
3
Field trip stop (Stop 1 is located outside the map area)

Figure 3. Geology map of the Sisson Brook area in west-central New Brunswick (from Fyffe et al. 2008). Figures 1 and 2 show location of this map area.

tuff; layers of 1 m thick, dark green, banded amphibolitic mafic tuffs; and light grey to greyish purple, medium-bedded, biotite-rich psammite (Lutes 1981). The age of this westernmost volcanic-bearing sequence in the Sisson Brook area is not known with certainty (Fyffe et al. 1988b). However, it may correlate with the Turnbull Mountain Formation of the Tetagouche Group (see below). Medium- to thick-bedded, light grey, fine-grained quartzite and greyish green shale lying immediately east of the volcanic-bearing sequence are assigned to the Miramichi Group (Fig. 3). The quartzose sequence of the Miramichi Group is conformably overlain to the east by rocks characteristic of the Tetagouche Group. These include 1) a lower section of pyritiferous black shale intercalated with minor flow-banded and brecciated felsic volcanic rocks, and fragmental mafic volcanic rocks correlated with the Hayden Lake Formation, and 2) an upper section of thin- to medium-bedded feldspathic to lithic wacke, and dark grey shale correlated with the Push and Be Damned Formation (Potter 1969; Lutes 1981).

Lutes (1981) considered the quartzose sedimentary rocks of the Miramichi Group in the Sisson Brook area to lie in the core of an anticline, flanked to the east and west by conformably overlying volcanic-bearing sequences of the Tetagouche Group. However, to the east, volcanic rocks of the Hayden Lake Formation are interbedded with black shale, whereas, to the west, they contain interbeds that are predominantly psammitic. Fyffe et al. (1988b) agreed that both volcanic sequences may represent part of the Tetagouche Group but, on the basis of abundant quartz flooding observed near the unexposed contact, interpreted the western sequence to be faulted against the Miramichi Group. The presence of such a fault on the western limb of the proposed anticline is consistent with the intensely sheared nature of rocks hosting the Sisson Brook mineralization (Fig. 3).

The contact between the western volcanic sequence and plutonic rocks of the adjacent Howard Peak pluton is not exposed on surface. However, fine-grained, dark green rocks containing layers rich in plagioclase augen and light grey rocks containing large feldspar augen (up to 1 cm in length) can be seen in core from near the contact. Geologists with Kidd Creek Mines and Geodex Minerals have suggested that these rocks are metamorphic equivalents of tuffaceous sedimentary rocks and felsic lapilli tuff (Mann 1981a, 1981b, 1982; Martin 2006). However, Fyffe et al. (2008) consider these rocks to be highly strained equivalents of gabbroic and granitic rocks that comprise the Howard Peak pluton (see below). To resolve this issue, a closer examination of local outcrops and drill core will be required to determine the nature and placement of the contact between the pluton and host rocks exposed farther to the east.

Interestingly, Mann (1980, 1981a) noted, on the basis of his observations of graded bedding and flame structures in drill core, that the western volcanic-bearing sequence apparently youngs to the east. Yet the sequence should have younged to the west if it had lain on the unfaulted western limb of an anticline. Thus, the western sequence is tentatively correlated with tuffaceous felsic and mafic rocks of the Turnbull Mountain Formation, which conformably underlies the Hayden Lake Formation northeast of Sisson Brook in the Napadogan area

(Poole and Neuman 2003). A considerable amount of stratigraphic section could be missing across the fault separating the Turnbull and Hayden Lake formations.

Plutons and Dykes

The Howard Peak Granodiorite is a medium-grained, foliated, hornblende–biotite granodiorite that grades eastward into, and becomes intermixed with, dark grey, medium-grained ophitic gabbro (Fig. 3). Both the granodiorite and gabbro are transected by dykes of massive to foliated, light greyish pink, equigranular granite (Fig. 4). The eastern margin of the pluton is intensely sheared and cataclastized, and it contains abundant elongated, schistose xenoliths derived from the adjacent folded country rocks (Lutes 1981; Venugopal 1982). The Nashwaak Granite is a massive, light greyish pink, medium-grained, equigranular to subporphyritic biotite granite that grades to a muscovite–biotite granite in the north. This granite has yielded a Rb–Sr muscovite age of 422 ± 4 Ma and a K–Ar muscovite age of 386 ± 5 Ma (Whalen and Theriault 1990). The aforementioned granitic dykes cutting the Howard Peak pluton are probably offshoots of the Nashwaak pluton (Fig. 4).

Massive, fine-grained granite porphyry dykes were intersected in drillhole SSN-26 near the southern end of Zone III of the Sisson Brook deposit (Fig. 3). The massive dykes (Fig. 5) were intruded post-tectonically into foliated gabbro of the Howard Peak pluton and have been interpreted as late offshoots of an assumed deeply buried stock that generated the mineralizing hydrothermal fluids at Sisson Brook (Mann 1981a; Nast 1985; Nast and Williams-Jones 1991). A porphyry sample from drillhole SSN-26 yielded a U–Pb age of 364.5 ± 1.3 Ma (Fyffe et. al. 2008) and therefore was emplaced during the Famennian Stage of the Late Devonian. It is essentially the same age as the volcanic complex (dated at 363.4 ± 1.8 Ma by U–Pb on zircon) at Mount Pleasant in southwestern New Brunswick (Tucker et al. 1998). The Mount Pleasant Caldera Complex is responsible for the polymetallic Sn–W–Mo–Bi–In mineralization described in Part 2 of this field guide.

The Late Devonian age of the porphyry at Sisson Brook indicates that magmatic activity in the central Miramichi Highlands spanned some 60 Ma beginning in the Late Silurian (Fyffe et al. 1981; Bevier and Whalen 1990; Whalen et al. 1996). This intrusive history is similar to that interpreted for the episodic emplacement of the composite Saint George Batholith (Fig. 2) in southern New Brunswick. Such long-lived magmatic–hydrothermal systems are conducive to forming a variety of granite-related mineral deposits (Ruitenberg and Fyffe 1982; McLeod et al. 1988; McLeod 1991; Thorne et al. 2002; Thorne et al. 2008).

STRUCTURAL GEOLOGY

The stratigraphic sequences in the Sisson Brook area have been folded into a series of north-northeasterly trending D_2 anticlines (cored by sedimentary rocks of the Miramichi Group) and synclines (cored by volcanic and sedimentary rocks of the Tetagouche Group), plunging 30° to the south (Lutes 1981; Fyffe 1982a, 1982b). A steep, northwesterly dipping, axial planar crenulation cleavage (S_2) developed during this deformational event. Folding has not been

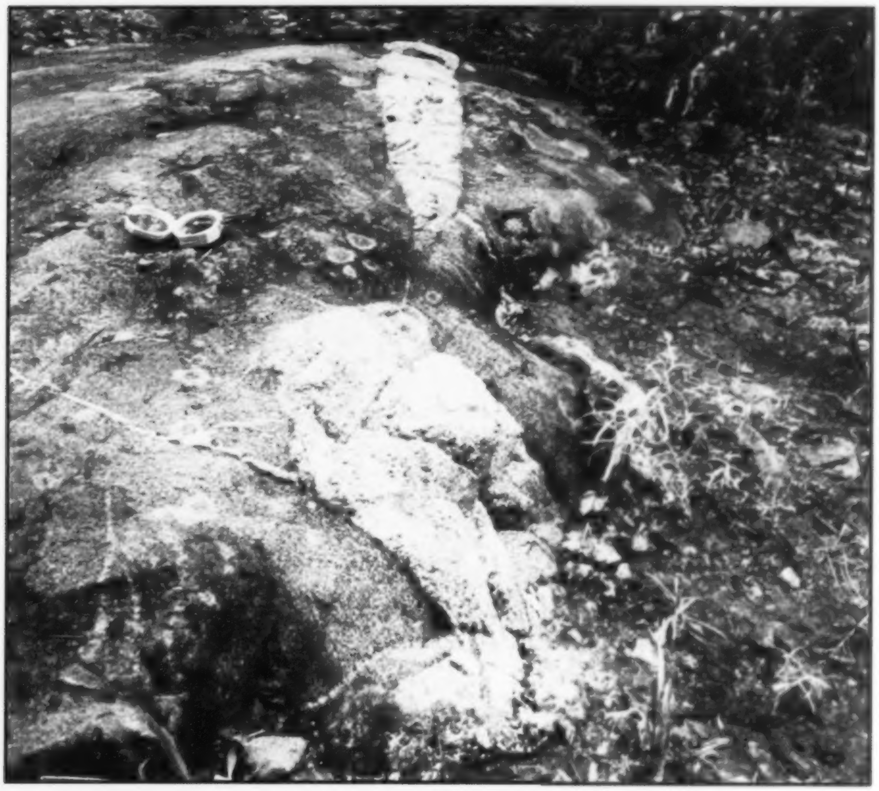

Figure 4. Boudinaged granitic dyke and dykelets cross-cutting foliated gabbro of the Howard Peak pluton along the western margin of the Sisson Brook deposit.

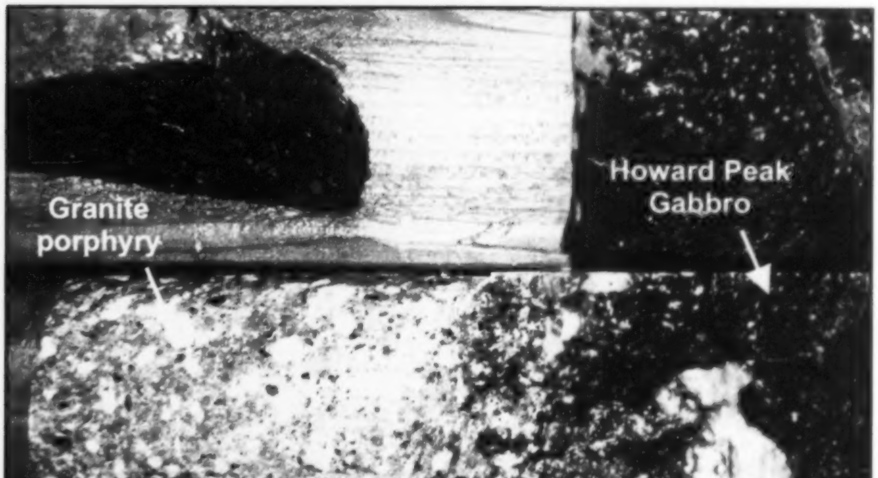
Granite porphyry
Howard Peak Gabbro
CENTIM

Figure 5. Massive, fine-grained granite porphyry dyke containing quartz and feldspar phenocrysts. Core from drillhole SSN-26 (see Fig. 3).

recognized in association with an earlier slaty cleavage (S_1), defined by fine-grained muscovite and chlorite oriented subparallel to bedding (Lutes 1981). A late northwesterly trending, steeply dipping fracture cleavage (S_3) is associated with steeply plunging kink bands. Porphyroblasts of cordierite, andalusite, and garnet in the thermal aureole of the Nashwaak pluton overprint S_1 and S_2 but are overprinted by S_3 (Lutes 1981; Nast 1985).

The gabbroic rocks of the Howard Peak pluton along the western margin of the Sisson Brook deposit (Fig. 3) possess a foliation defined by prominent melanocratic and leucocratic bands or by weakly aligned plagioclase and amphibole crystals (Lutes 1981; Nast 1985). The foliation trends subparallel to the S_2 fabric in the country rocks along the eastern boundary of the pluton. Therefore, emplacement of the Howard Peak pluton likely took place during the D_2 deformational event. Granitic dykes transecting and partially assimilating the gabbroic rocks vary from weakly foliated to unifoliate (Fig. 6). Differing orientations of the foliation in some gabbroic xenoliths indicate that they were rotated during their incorporation into the granite. The granitic dykes are likely offshoots of the Nashwaak pluton, which therefore must have been emplaced during the waning stage, and after the cessation, of D_2 deformation. A prominent set of joints oriented at 120° transects the foliation in the plutonic rocks (Fig. 7). These tensional joints have developed parallel to the maximum stress direction in the region (Lajtai and Stringer 1981).

A number of major, northerly to north-northeasterly trending faults that displace D_2 fold structures have been mapped in central New Brunswick (Fyffe 1982a, 1982b). One such fault has been interpreted to truncate the stratigraphic section on the western limb of the anticline in the Sisson Brook area (Fyffe et al. 2008). The north-northeasterly lineament controlling the course of Sisson Brook may mark the main trace of this fault (Fig. 3). The existence of a high-strain zone in the immediate vicinity of the Sisson Brook deposit is evidenced, not just by the missing stratigraphic section, but also by the increased intensity of structural fabrics from west to east across the area.

Bedrock exposure in the area is sparse. However, deformation that appears as a weak foliation in plutonic rocks west of the deposit (see ***Geological Setting***, above) is manifested as a strong cataclastic fabric farther to the east. A large trench in Zone III of the Sisson Brook deposit (Fig. 3) exposes gabbroic rocks with a penetrative foliation and a granulated fine-grained groundmass containing small porphyroclasts of plagioclase (Fig. 8). Granitic dykes cutting the gabbroic rocks exhibit a prominent cataclastic foliation, along which augen of feldspar are aligned (Fig. 8). The development of this localized high-strain zone apparently provided permeable pathways for the introduction of hydrothermal fluids that were the source of mineralization at Sisson Brook. Any major movement along this north-northeasterly trending shear in Zone III must have taken place before injection of the cross-cutting, west-northwesterly trending, molybdenite-bearing quartz veins (Fig. 8; see ***Deposit Geology***, below). However, there is evidence of some late minor sinistral displacement of these veins (Fig. 9).

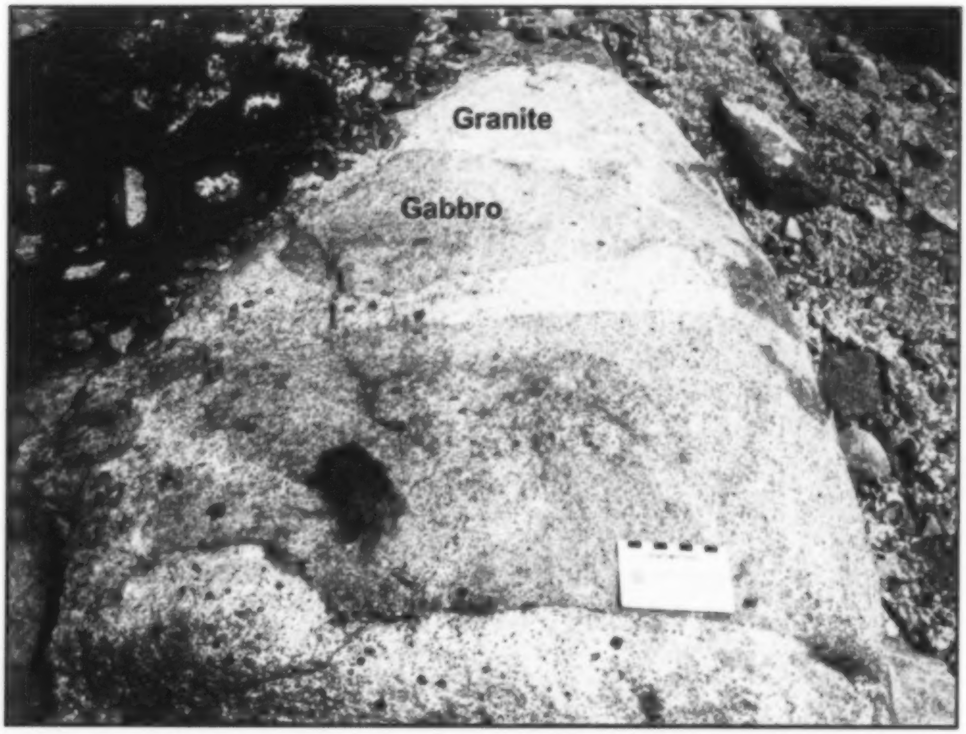
Granite
Gabbro

Figure 6. Granitic dykes cross-cutting the Howard Peak Gabbro (scale in centimetres).

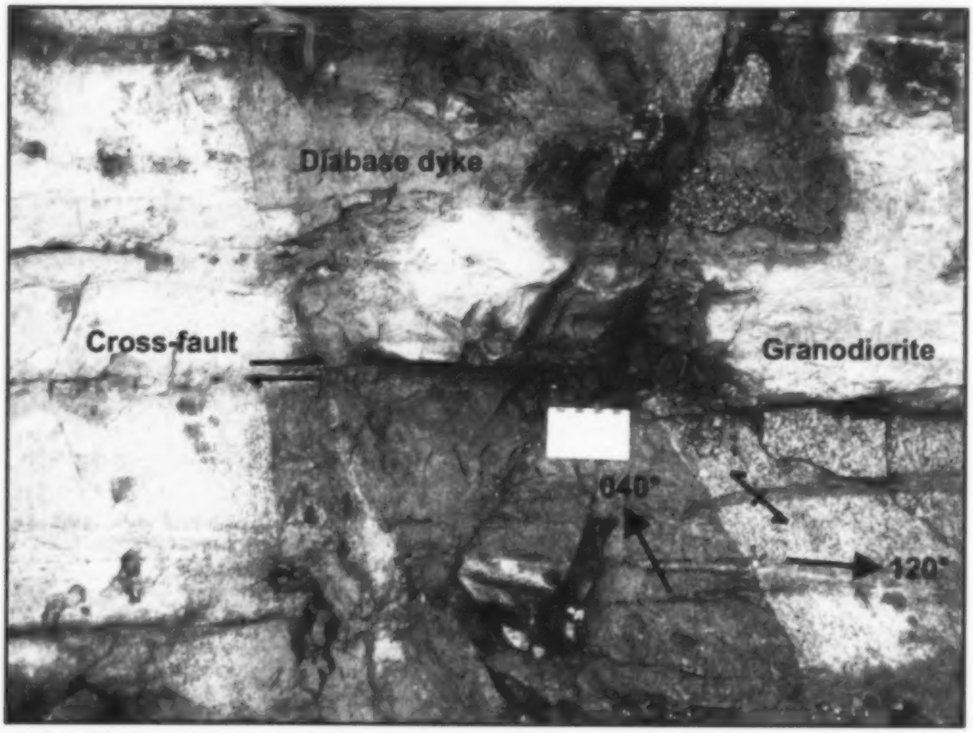
Diabase dyke
Cross-fault
Granodiorite
040°
120°

Figure 7. Granodiorite in Zone I of the Sisson Brook deposit, cross-cut by a diabase dyke that is offset along prominent west-northwesterly trending microfaults (scale in centimetres).

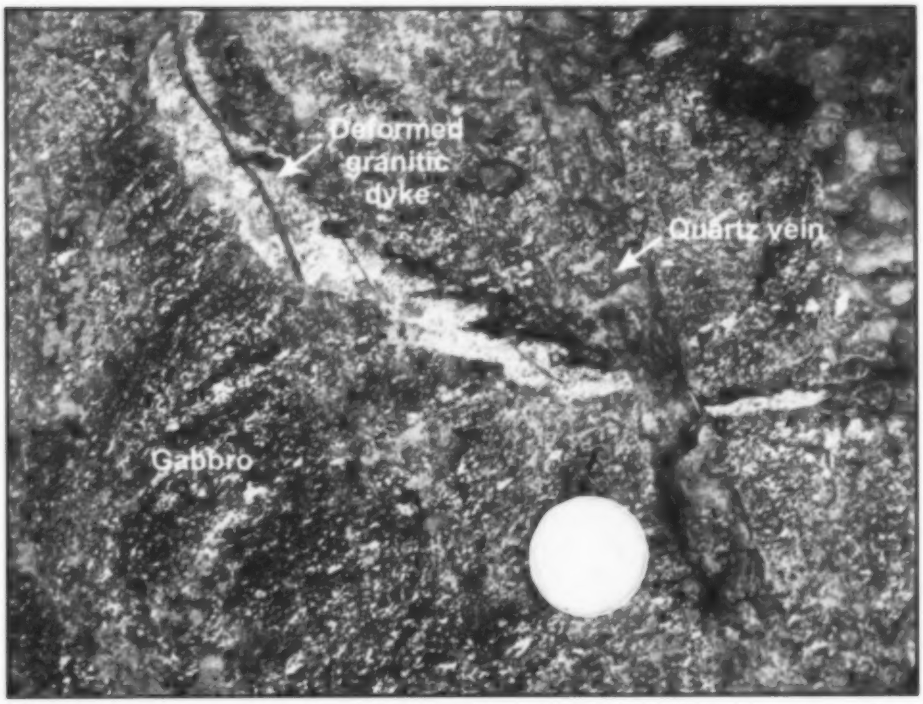

Figure 8. Gabbro containing plagioclase porphyroclasts, exposed in the trench at Zone III, Sisson Brook deposit (Stop 4). Note the deformed granitic dykes and the cross-cutting, northwesterly trending quartz vein. Coin diameter is 2.7 cm.

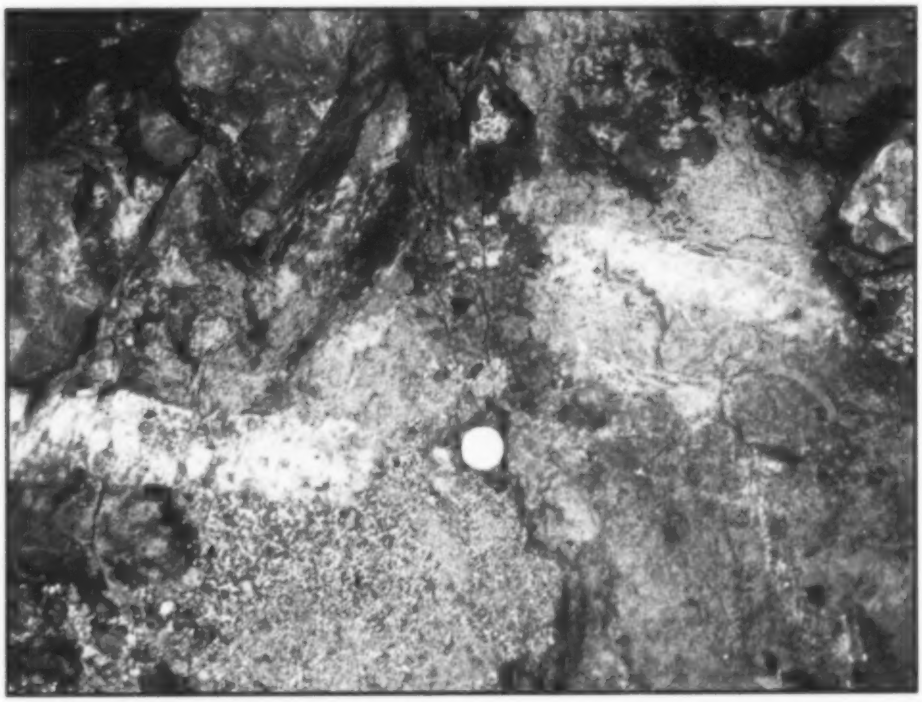

Figure 9. Sinistral offset of an easterly trending quartz–feldspar vein along a northerly trending fault on the southern margin of the trench at Zone III. View looking north. Coin diameter is 2.7 cm.

Evidence for late major sinistral displacement along the high-strain zone can be observed in the Zone I trench at the northern end of the Sisson Brook deposit. Schistosity–shear fabrics indicate that an interbedded sequence of siltstone and tuff of the Turnbull Mountain Formation was juxtaposed against granodioritic rocks of the Howard Peak pluton along a north-northwesterly trending sinistral shear zone. The shear abruptly truncates a west-northwesterly trending joint set prominently displayed in the granodiorite (Fig. 7), indicating that a considerably greater amount of late sinistral movement occurred in Zone I than in Zone III. Some limited movement along the joint set is shown by small dextral displacement of the margins of two diabase dykes cutting the granodiorite (Fig. 7). The minor dextral and dominant sinistral movements likely were caused by the same stress field, given that the previously developed joint set was oriented similarly to the conjugate shear direction of the principal stress axis. The north-northwesterly trending shear zone exposed in the Zone I trench is interpreted to be a horsetail splay off the main north-northeasterly trending, high-strain shear zone along the eastern margin of the Howard Peak pluton in Zone III.

GLACIAL HISTORY

West-central New Brunswick presumably was glaciated many times during the Pleistocene. However, no evidence is known for glaciations prior to the Wisconsinan Stage, which occurred in the interval between about 110 ka and 10 ka (Seaman 2004). (Note: all glaciation dates cited herein are in thousands of radiocarbon years before present (ka), which are not precisely equivalent to calendar years.)

The Early Wisconsinan glaciation in New Brunswick has been divided into the early Caledonia Phase, characterized by east-southeasterly ice flow; and the late Caledonia Phase, characterized by southeasterly ice flow (Seaman 2004). Stea et al. (1998) dated the Caledonia Phase at 75 ka to 40 ka. Rampton et al. (1984) related the Caledonia Phase and subsequent glaciations to the action of local Appalachian glaciers, rather than to the continental-scale Laurentide Ice Sheet.

Evidence for the early Caledonia Phase is sparse in west-central New Brunswick. Until recently, it comprised scattered occurrences of apparently old easterly trending glacial striae (Rampton et al. 1984) and a partially reworked east-southeasterly trending dispersal train from the Carboniferous redbed sequence near Cloverdale (Seaman 2000, 2004), about 25 km west-southwest of Sisson Brook. The lowest of three tills exposed in the main Sisson Brook exploration trench was recently assigned to the early Caledonia Phase (Seaman and McCoy 2008). The late Caledonia Phase was inferred to be responsible for sculpting the bedrock topography over much of southwestern New Brunswick (Seaman 2004). However, the phase has not been definitively identified in west-central New Brunswick, as Late Wisconsinan flow of similar trend is also known in this area (see below).

During the Middle Wisconsinan (40–22 ka, according to Stea et al. 1998), glaciers disappeared from at least part of west-central New Brunswick. At the Half Moon Pit site 10 km north-northeast of Sisson Brook, Lamothe (1992) identified an organic-bearing colluviated

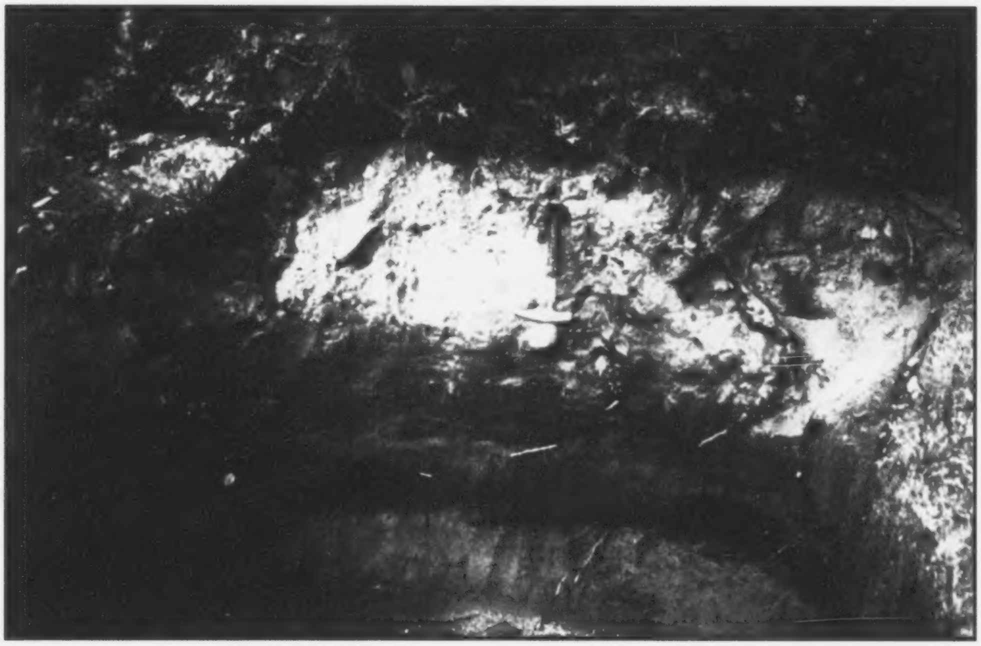

Figure 10. Till profile at the Half Moon Pit sample site in the Sisson Brook area. Hammer for scale.

sand of Middle Wisconsinan age (radiocarbon-dated at >36 ka) beneath the surface Late Wisconsinan till (Fig. 10). Unpublished observations by Seaman suggest that the organic-bearing material lies in a kettle hole in a glaciofluvial deposit, supporting Lamothe's (1992) interpretation that the material was formed in a cool environment.

The Late Wisconsinan glaciation of New Brunswick was divided into five phases by Rampton et al. (1984). However, the results of new radiocarbon dates and of recent investigations (both onshore and on the offshore Atlantic continental shelf) have led to a revised chronological sequence that comprises four glacial phases (Stea et al. 1998):

- Escuminac Phase (c. 22–18 ka), during which glacial flow from the Escuminac Ice Centre in the Gulf of St. Lawrence traversed the Maritime provinces and reached its maximum extent at the edge of the continental shelf;
- Scotian Phase (c. 18–15 ka), during which the Escuminac Ice Centre disintegrated, leading to the development of multiple ice centres or divides over the Maritime provinces;
- Chignecto Phase, representing a minor glacial readvance (c. 13 ka) to ice margins approximately correlative with the modern coastline (not the same as the "Chignecto Phase" of Rampton et al. 1984); and
- Collins Pond Phase, during which remnant glaciers reformed or regrew due to climatic deterioration during the Younger Dryas Stadial (11–10 ka).

Rampton et al. (1984) indicated that ice flow in west-central New Brunswick during the early part of the Late Wisconsinan was southeastward to south-southeastward. Cross-cutting relationships in southwestern New Brunswick indicate that the southeastward flow preceded the south-southeastward flow (Seaman et al. 1993). It has not been possible to differentiate the late Caledonia Phase southeastward flow from the later flow of similar trend. However, the fabric of surficial till at the Half Moon Pit site suggests deposition by a southeastward-flowing glacier (Seaman 2006; his Table 1, grid point no. CS-WX03b-1), supporting a Late Wisconsinan flow in this direction.

The dispersal train from Sisson Brook displays a similar southeastward trend, except for a short, southerly trending dogleg for the first few kilometres caused by the topographic effects of Nashwaak Ridge. The train is about 20 km to 30 km long (Seaman 2007). To the west and southwest, dispersal trains with similar magnitudes trend south-southwesterly (Seaman 2000). The consistency of ice-flow trend required to generate such dispersal trains suggests flow from a stable and fairly stationary source area. This implies that the dispersal trains were formed during the Escuminac Phase, although most likely by ice from the North Maine Ice Divide (Rampton et al. 1984).

During the Scotian and Chignecto phases, west-central New Brunswick was subject to wide variations in ice-flow directions, as migrating ice centres or divides resulted in flow in most directions of the compass (Seaman et al. 1993; Seaman 2006, 2007). However, these glaciers had limited erosive effectiveness, as evidenced by the local occurrence of up to ten different striae sets on a single outcrop surface (Seaman 1991), and by the widespread preservation of previously formed dispersal trains. In many cases, these later glaciers seem to have been capable only of adding a few striae to bedrock surfaces and locally reworking the pre-existing till. One example of local reworking appears in the southeasterly trending Sisson Brook dispersal train at till sample site CS-W10b (Seaman 2003). Here, the till fabric (see Seaman 2006, his Table 1) suggests a northeastward ice flow, compatible with a late striae trend on a bedrock outcrop 15 km to the northeast. Such hybrid tills—tills formed during one glacial event and reworked during one or more subsequent events—are common in southwestern New Brunswick (e.g., Allard and Pronk 2003).

Some of the later ice flows were strong enough to locally erase the previously formed dispersal trains. For example, the south-southeasterly trending Cloverdale dispersal train (Seaman 2001) becomes discontinuous near its tip. A till fabric measurement made in one of the gaps (Seaman, unpublished data) indicated south-southwestward ice flow from a later, probably Scotian Phase, trend. A similar fabric trend was measured for the middle till at Sisson Brook (Seaman and McCoy 2008), suggesting a comparable age.

By the end of the Chignecto Phase, much of New Brunswick had been deglaciated. However, the climatic deterioration of the Younger Dryas led either to the regrowth of remnant glaciers or to the inception of new ones, such as the Collins Pond Phase. West-central New Brunswick was invaded by westward-flowing ice from the Gaspereau Ice Centre (Seaman 2006). The Younger Dryas till locally blankets previously deposited tills, as at Sisson Brook, where it is between 1 m and 2.5 m thick. Dates on organic material from within this till indicate that the

Younger Dryas glacier grew rapidly and reached its maximum extent shortly after 11 ka (Seaman and McCoy 2008). The rapid growth supports the interpretation of regrowth from a remnant 'seed' glacier. Ice retreat from the Younger Dryas maximum was also rapid: a date on basal peat from a surficial channel fill at Sisson Brook indicates that the area was ice-free by the middle of the Younger Dryas, c. 10.5 ka (Seaman and McCoy 2008). Disintegration of the Younger Dryas glacier resulted in the deposition of extensive ablation till deposits (hummocky disintegration moraine) in some areas around Sisson Brook (Snow and Coker 1987).

EXPLORATION HISTORY

Texasgulf Inc. staked claims in the Sisson Brook area in 1978 to cover ground where Penarroya Canada Ltée. had intersected tungsten–copper mineralization in three holes drilled in 1969 (Rabinovich 1969; Moore 1979). Regional geochemical surveys conducted by the New Brunswick Department of Natural Resources in 1972 also indicated that stream silts in the area contained anomalous molybdenum values (Austria and Chork 1976).

Diamond drilling (11 holes) conducted by Texasgulf in 1979 to test geophysical anomalies in the central portion of its claim group resulted in the discovery of the Zone I and Zone II tungsten–copper mineralization at Sisson Brook (Mann 1981b). The following year, another 12 holes were drilled to delineate the extent of the two known zones (Mann 1980). Kidd Creek Mines Ltd. drilled an additional nine holes south of the known zones in 1981, which led to the discovery of tungsten–molybdenum mineralization in Zone III. One of these 1981 holes (SSN-26; see Fig. 3) intersected dykes of massive granite porphyry (Mann 1981a). Another eight holes were drilled in the following year to test Zone III along strike and at depth (Mann 1982).

Champlain Resources Inc. staked ground in the Sisson Brook area in 1997, and Geodex Minerals Ltd. optioned the Sisson Brook claim group from Champlain Resources in 2004. In the following year, Geodex carried out geological mapping, prospecting, soil sampling, geophysical surveys, and drilling (nine holes) on the property. Geodex subsequently conducted a fence-drilling program on Zone III to calculate National Instrument 43-101, *Standards of Disclosure for Mineral Projects* resources for the deposit (Martin 2006; Ozturk 2007; Geodex Minerals Ltd. 2008). This drill program comprised 30 holes totalling 7784 m in 2006, and 83 holes totalling 20,178 m in 2007, which included two metallurgical holes. In 2008 Geodex conducted 11,800 m of both infill and exploration drilling on adjacent targets as well as geotechnical, environmental, and community studies.

DEPOSIT GEOLOGY

Host Rocks

The mineralization at Sisson Brook occurs in a series of structurally controlled quartz veins in highly silicified shear zones along the eastern margin of the Howard Peak pluton (Fig. 3). Zones I and II at the north end of the deposit strike north-northwesterly and dip steeply to the west, parallel to the trend of a late sinistral shear (see ***Structural Geology***, above). Zone I is hosted by a thin-bedded sequence of dark grey siltstone and tuff. The bedding trends to the north-northeast and dips steeply to the east. The mineralization in Zone I has been traced along strike for about 950 m and varies in thickness from 2 m to 36 m. Zone II is hosted in gabbroic rocks about 100 m west of Zone I and has been traced along strike for 400 m. Quartz veins associated with the mineralization in Zones I and II range in width from about 0.5 cm to 3 cm.

Zone III strikes north-northeasterly and dips steeply to the northwest (Mann 1980, 1981a, 1981b, 1982), parallel to the trend of a major shear zone (see ***Structural Geology***, above). The mineralization is hosted by sheared and silicified gabbroic rocks of the Howard Peak pluton and associated cataclastically deformed granitic dykes that likely represent offshoots of the Nashwaak pluton. Zone III has been traced along strike for 1100 m with a maximum thickness of about 400 m (Geodex Minerals Ltd. 2008).

Mineralization

Ore minerals at Sisson Brook consist mainly of wolframite and chalcopyrite in Zones I and II, and scheelite and molybdenite in Zone III. According to Nast and Williams-Jones (1991), a low fluid–rock ratio governed the style of mineralization at Sisson Brook. Thus, precipitation of scheelite was controlled by the composition of the calcium-rich, gabbroic wall rocks of Zone III, whereas precipitation of wolframite was governed by the calcium-poor, sedimentary wall rocks of Zone I.

Scheelite in Zone III tends to be concentrated in quartz veins that parallel the north-northeasterly trending shear fabric; conversely, molybdenite is concentrated in cross-cutting quartz veins oriented between 120° to 140°. This latter trend is approximately parallel to the prominent set of joints in the less deformed gabbroic and granitic rocks along the western margin of Zone III. Similar molybdenite-bearing quartz veins occur in brittle fractures transecting the Late Devonian granite porphyry observed in drill core from the southern part of Zone III.

RESOURCE ESTIMATES

Calculations by Texasgulf Inc. indicated that Zone I contains an estimated 6.8 Mt of 0.21% WO_3 and 0.35% Cu, and that Zone II contains an estimated 1.4 Mt of 0.14% WO_3 and 0.09% Cu (Mann 1980; Martin 2006).

A mineral resource estimate for Zone III (Table 1) was calculated on the basis of assay results from the 2008 drilling program (Geodex Minerals Ltd. 2009). A mineral resource estimate was also calculated for the Ellipse Zone, located a few hundred metres south of Zone III within the diorite (Table 2; Geodex Minerals Ltd. 2009).

Table 1. Mineral resource estimate for Zone III, Sisson Brook deposit, west-central New Brunswick.

Threshold Equivalent WO_3 %	Measured Tonnes (Mt)	WO_3 %	Mo %	Indicated Tonnes (Mt)	WO_3 %	Mo %	Inferred Tonnes (Mt)	WO_3 %	Mo %
0.025	**26.6**	0.072	0.025	**257.3**	0.062	0.019	**223.6**	0.055	0.018
0.075	**19.4**	0.086	0.030	**151.1**	0.082	0.026	**118.7**	0.073	0.027
0.125	**11.0**	0.109	0.037	**69.1**	0.107	0.034	**47.8**	0.097	0.036
0.175	**5.1**	0.135	0.044	**26.7**	0.131	0.045	**5.9**	0.120	0.049
0.225	**1.8**	0.168	0.053	**9.3**	0.152	0.058	**5.4**	0.138	0.064

Note: WO_3 equivalent = WO_3 % + 2.02 Mo %

Table 2. Mineral resource estimate for Ellipse Zone, Sisson Brook deposit.

Threshold Equivalent WO_3 %	Measured Tonnes (Mt)	WO_3 %	Mo %	Indicated Tonnes (Mt)	WO_3 %	Mo %	Inferred Tonnes (Mt)	WO_3 %	Mo %
0.025	**1.1**	0.082	0.023	**28.3**	0.072	0.024	**36.5**	0.061	0.019
0.075	**0.9**	0.092	0.027	**22.5**	0.081	0.027	**23.4**	0.073	0.026
0.125	**0.5**	0.112	0.034	**10.4**	0.105	0.038	**8.6**	0.091	0.041
0.175	**0.2**	0.135	0.044	**4.6**	0.121	0.05	**3.4**	0.102	0.057
0.225	**0.1**	0.146	0.068	**1.5**	0.139	0.067	**0.9**	0.094	0.094

Note: WO_3 equivalent = WO_3 % + 2.02 Mo %

COMPARISON WITH OTHER NEW BRUNSWICK POLYMETALLIC DEPOSITS

Mount Pleasant Deposit

The possible genetic relationship of tungsten–molybdenum mineralization at Sisson Brook to the nearby Late Devonian granite porphyry invites comparison with the endogranitic tungsten–molybdenum–tin mineralization at Mount Pleasant in southwestern New Brunswick (Fig. 2).

The Mount Pleasant deposit is associated with two subvolcanic intrusions emplaced into the Late Devonian Mount Pleasant Caldera Complex (Fig. 2), located along the northern flank of the Saint George Batholith. The subvolcanic intrusions—the McDougall Brook and the Mount Pleasant granitic suites—are related to early and late stages of caldera development, respectively. The suites are distinguished on the basis of their textural and mineralogical characteristics and their distinctive chemical fractionation trends (Kooiman et al. 1986; McCutcheon et al. 1997; Yang et al. 2003; Inverno and Hutchinson 2006). K–Ar dating of biotite from a hornfelsic sedimentary breccia in the contact aureole of the Mount Pleasant Granitic Suite yields an age of 360 ± 9 Ma (after Hunt and Roddick 1990), compared with the U–Pb age of 363.4 ± 1.8 Ma on volcanic rocks of the caldera complex (Tucker et al. 1998).

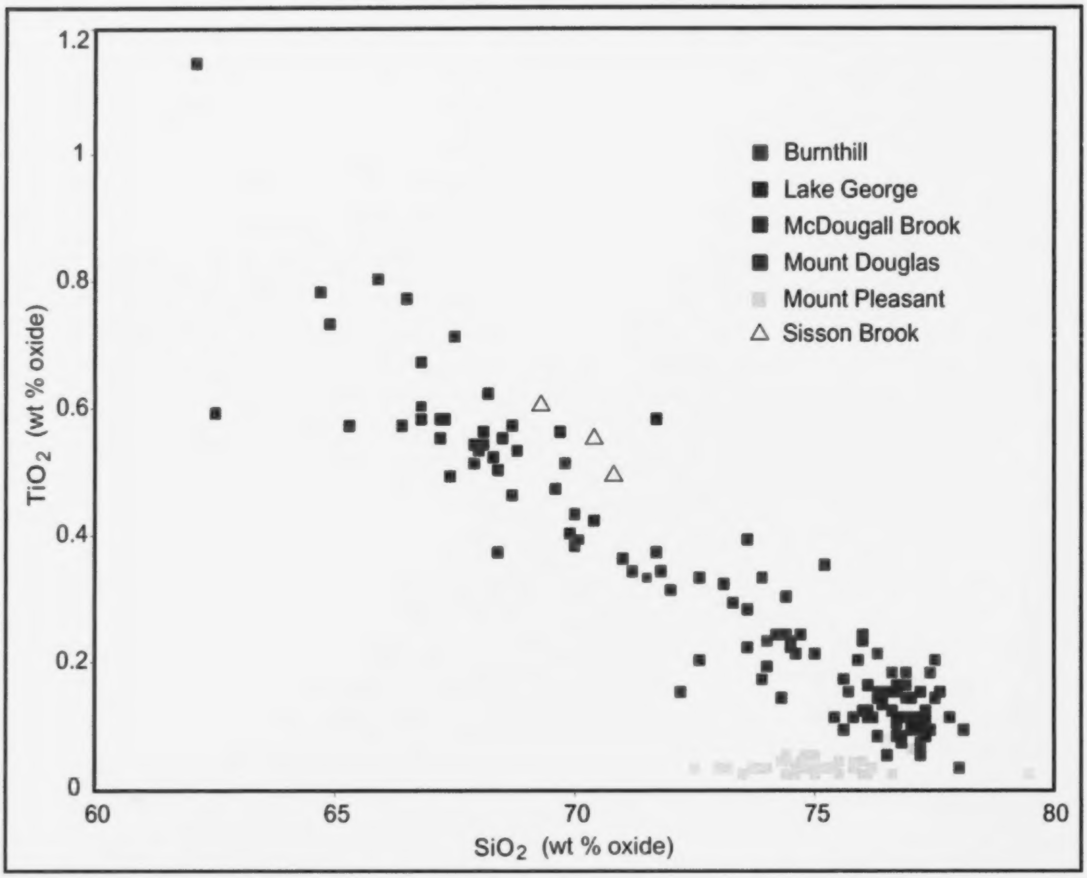

Figure 11. SiO_2 vs TiO_2 diagram for granitic rocks at Burnthill, Lake George, McDougall Brook, Mount Douglas, Mount Pleasant, and Sisson Brook (data from Kooiman et al. 1986; MacLellan and Taylor 1989; McLeod 1991; Nast and Williams-Jones 1991; McCutcheon et al. 1997; Yang et al. 2002, 2003; Inverno and Hutchinson 2006; Leonard et al. 2006).

The tungsten–molybdenum–tin mineralization at Mount Pleasant is genetically related to the Mount Pleasant Granitic Suite. Petrochemically, this suite consists of highly evolved, specialized granites (Fig. 11). They are strongly enriched in the incompatible elements such as F, Li, Rb, Cs, U, Th, and Nb; and they are depleted in the more compatible elements of Ca, Mg, Fe, Ti, Sr, and Ba (Kooiman et al. 1986; Yang et al. 2003; Inverno and Hutchinson 2006). Mineralization at Mount Pleasant occurs as disseminated grains and rare coarse crystals of wolframite and molybdenite in fractures and veinlets hosted by a hydrothermal granite breccia that is altered to a quartz–topaz–sericite–fluorite greisen. Cross-cutting, chlorite-rich veins measuring 1 cm to 3 m wide contain cassiterite, stannite and base metal sulphides (Kooiman et al. 1986; Inverno and Hutchinson 2004).

Endogranitic tungsten–molybdenum–tin mineralization is also associated with the Late Devonian Mount Douglas pluton in the eastern portion of the Saint George Batholith (Fig. 2). Textural varieties include coarse- to medium-grained, subporphyritic to equigranular rapakivi, biotite granite, and fine-grained porphyritic granite. The $^{40}Ar/^{39}Ar$ dates on muscovite from mineralized greisen-vein systems in the granite range from 363 ± 5 Ma to 361 ± 5 Ma

(McLeod 1991), ages that coincide with the timing of volcanism at Mount Pleasant. However, the more deeply emplaced Mount Douglas pluton does not exhibit the extreme degree of fractionation seen in the subvolcanic Mount Pleasant Granitic Suite (Fig. 11).

Burnthill Deposit

Tungsten–molybdenum–tin deposits associated with highly evolved granitic intrusions also occur in the central Miramichi Highlands (Ruitenberg and Fyffe 1982). The Burnthill Granite, located about 25 km north-northeast of the Sisson Brook deposit (Fig. 2), is the largest of five Middle Devonian granitic plutons that intrude Cambrian to Early Ordovician quartzite of the Miramichi Group and Ordovician volcanic and sedimentary rocks of the Tetagouche Group (Fyffe 1982b).

The subcircular Burnthill pluton is composed predominantly of pink, medium- to coarse-grained, subporphyritic biotite granite that grades into, and is locally cross-cut by, medium- to fine-grained, equigranular biotite ± muscovite granite in the south. The polydeformed sedimentary rocks in the thermal aureole contain cordierite and andalusite within 500 m of the granite contact (Taylor et al. 1987; MacLellan et al. 1990). ^{40}Ar/^{39}Ar dating indicates that intrusion and cooling of the Burnthill pluton (386 ± 5 Ma on igneous biotite) and emplacement of mineralized greisen veins (383 ± 5 Ma on muscovite selvage) took place during the Middle Devonian (Taylor et al. 1987). Endogranitic veins that intersect at depth in the apical part of a buried cupola along the southeastern margin of the exposed Burnthill pluton are continuous with exogranitic veins that cut quartzite at the surface (Taylor et al. 1987). The greisen-bordered quartz veins are from 2.5 cm to 120 cm wide and trend to the southeast, parallel to a prominent, steeply dipping joint in the host quartzite. The veins contain wolframite in crystals up to 4 cm in length, molybdenite, scheelite, cassiterite, and base metal sulphides. MacLellan et al. (1990) provide convincing petrochemical evidence that metal-rich hydrothermal fluids accumulated in the upper part of the more highly evolved, southern portion of the Burnthill pluton during fractional crystallization of the silicate melt. The range in chemical composition within the Middle Devonian Burnthill pluton is very similar to that of the Late Devonian Mount Pleasant subvolcanic pluton.

Lake George Deposit

Tungsten–molybdenum–antimony mineralization is associated with less evolved intrusive rocks at the former Lake George mine (Fig. 2), approximately 40 km west of Fredericton. The Early Devonian Lake George Granodiorite dated by U–Pb (zircon) at 412 ± 2 Ma (McLeod et al. 2003), intrudes folded Silurian calcareous to noncalcareous wacke and shale of the Kingsclear Group along the southeastern margin of the Pokiok Batholith (Fig. 2). The fine- to medium-grained, plagioclase–hornblende–biotite-phyric granodioritic stock is buried at a depth of 350 m, but dykes of similar composition are exposed at surface. The main stibnite-bearing quartz vein system, exposed at surface, trends to the east and dips at about 35°N, cross-cutting the apex of the stock at depth. The stibnite-bearing veins also cross-cut earlier scheelite–molybdenite-bearing carbonate–quartz stockworks within a skarn zone on the periphery of the stock (Morrissy and Ruitenberg 1980; Scratch et al. 1984; Seal et al. 1987; Yang et al. 2002; Leonard et al. 2006). Yang et al. (2004) concluded, on the basis of fluid inclusion studies, that the tungsten–molybdenum–tin-bearing fluids were enriched in, and exsolved from, the cooling granitic magma.

Clarence Stream Deposit

Gold mineralization at the Clarence Stream deposit is associated with a granite-related polymetallic mineral assemblage in two separate zones, designated as the Main Zone and the Anomaly A Zone (Fig. 1).

Mineralization at the Main Zone occurs in a series of parallel quartz veins localized within a steep, northeasterly trending, brittle–ductile shear zone along the northern boundary of the Early Devonian Magaguadavic Granite. The shear zone cuts volcaniclastic sedimentary and volcanic rocks of the Silurian Waweig Formation and is intruded by gabbroic and minor felsite dykes. The Main Zone is broadly representative of a typical Au–Sb metal association, consisting mainly of arsenopyrite, pyrrhotite, pyrite, berthierite, minor chalcopyrite, sphalerite, native gold, aurostibite, bismuthinite, and gold–antimony intergrowths. The source of the gold-bearing fluids responsible for the mineralization at the Main Zone is interpreted to be the nearby, relatively unevolved Magaguadavic Granite (Thorne et al. 2008; Yang et al. 2008).

Gold mineralization at the Anomaly A Zone occurs in quartz–sulphide stockwork veins hosted within openly folded thrust zones in polydeformed Ordovician quartzose sandstones of the Kendall Mountain Formation. The quartz vein system contains pyrrhotite, pyrite, stibnite and lesser arsenopyrite, berthierite, native gold, aurostibite, and native antimony as well as a variety of other Sb-bearing minerals. The Anomaly A Zone is interpreted as a distal equivalent of the Main Zone: both zones have a similar metal association, except that the former lacks Bi-bearing minerals and contains more abundant Sb than does the latter (Watters et al. 2008).

DISCUSSION

The large-tonnage, low-grade Sisson Brook tungsten–molybdenum–copper deposit is localized in a northerly trending, high-strain, silicified zone along the eastern margin of the Howard Peak pluton. Gabbroic rocks of the Howard Peak pluton to the west of the high-strain zone exhibit a much weaker fabric and were intruded by generally massive granitic rocks of the Nashwaak pluton between the Late Silurian and Early Devonian (Rb–Sr muscovite age of 422 ± 4 Ma and K–Ar muscovite age of 386 ± 5 Ma).

Granitic dykes representing offshoots of the Nashwaak pluton in Zone III of the Sisson Brook deposit possess a strong cataclastic foliation. The foliation largely pre-dates silicification associated with the mineralization process, which indicates that the introduction of metal-bearing hydrothermal fluids post-dated emplacement and the local high-strain deformation observed in the Nashwaak granitic dykes of Zone III. Early north-northeasterly trending hydrothermal quartz veins tend to contain scheelite, whereas later west-northwesterly trending, cross-cutting veins are rich in molybdenite. Wolframite-bearing quartz veins in Zone I are associated with late north-northwesterly trending sinistral shears that displace the west-northwesterly trending molybdenite-bearing vein system.

Late Devonian granite porphyry dykes (U–Pb zircon age of 364.5 ± 1.3 Ma) cutting gabbro in a drillhole at the southern end of Zone III are transected by molybdenite-bearing quartz veins, raising the possibility that these dykes are the source of the hydrothermal fluids. As noted above, similar molybdenite-bearing veins cut across north-northeasterly trending, scheelite-bearing quartz veins at a high angle in the high-strain silicified zone exposed in a trench in Zone III farther to the north.

Limited whole-rock geochemical data (Nast 1985) suggest that, in terms of chemical composition, the granite porphyry at Sisson Brook resembles the Lake George stock more closely than the other granitic intrusions discussed above. Both the Sisson Brook and Lake George granitic rocks lack the extensive fractionation and associated greisen-type alteration that characterize granites associated with the Mount Pleasant, Mount Douglas, and Burnthill tungsten–molybdenum–tin deposits (Fig. 11).

Late crystallization of highly fractionated granites may account for the higher grade, smaller tonnage deposits at Mount Pleasant, Mount Douglas, and Burnthill (Strong 1981; Kooiman et al. 1986; MacLellan and Taylor 1989; McLeod 1991). However, another mechanism of metal concentration seemingly is needed to generate the low-grade, large-tonnage deposit at Sisson Brook. As Kirkham and Sinclair (1988) pointed out, the huge volume of hydrothermal fluids required to produce large-tonnage, granite-related mineral deposits could not have been generated by the small intrusive bodies commonly associated with such deposits. Shinohara et al. (1995) proposed an alternative scenario, whereby the convective transport of volatiles to shallow depths from deep within a slowly crystallizing magma chamber could scavenge metals from a large volume of granitic magma.

It therefore appears that a fairly long-lived, deeply buried magma chamber must have existed in the Sisson Brook area to produce the required quantity of metal-bearing hydrothermal fluids. Thus, the Late Devonian granite porphyry is likely not the direct source of the hydrothermal fluids at Sisson Brook but instead represents a relatively young system of dykes that tapped the deeper, degassed part of a magma chamber during the waning stage of the mineralizing process.

STOP DESCRIPTIONS

Stop 1: Ablation Till

From Fredericton, head west on Highway 102 until the exit for the Mactaquac Dam. Cross the Mactaquac Dam on Mactaquac Road and turn right on Rocky Road. Turn left at the junction with Route 616 and proceed to the junction with Route 104. Begin road log at this junction. Turn left onto Route 104 and continue 18 km to intersection and turn right onto the Nackawic Haulage Road. Drive another 18.9 km and stop at the gravel pit on the left side of the road.

Hazards: Logging trucks regularly use this road. Please be aware of truck traffic and stay well off to the side of the road.

This roadside borrow pit exposes up to 5 m of ablation till in a hummocky disintegration moraine. The material was transported in the englacial or supraglacial zones (within, or on top of, the the glacier, respectively) and deposited during the final melt-out of a stagnant glacier. It is commonly derived from a different direction or source than the basal till formed beneath an active glacier and therefore comprises a different geochemical population. In this area, the basal till was formed by the Late Wisconsinan Escuminac Phase glacier. The glacier had a southeast to south-southeast flow that partially reworked an older till formed by the east-southeastward-flowing early Caledonia Phase (Early Wisconsinan) glacier. In contrast, the ablation till was deposited either at the end of the Chignecto Phase following a period of northeastward ice flow, or during the Collins Pond Phase (Younger Dryas) near the western margin of the Gaspereau Ice Centre in central New Brunswick (Seaman 2006).

Table 3 compares average geochemical, grain size, and pebble lithology data for ablation and basal till sites within 3 km of Stop 1. The ablation till values are based on two samples from this section (geochemical, textural, and lithological data only) and on samples from two sites reported in Seaman (1999). The basal till values are based on samples from nine sites: seven from Seaman (1999) and two from Seaman (2002). These values clearly indicate that the ablation till has a largely local, granitic character, whereas the basal till includes input from other rock types marginal to the granite (that may host mineral deposits). Consequently, when collecting soil or till samples for geochemical analysis, care should be taken to note the soil parent material. Subsequent analysis should treat each till type as a distinctly different population, rather than grouping all data into a single dataset.

Stop 2: Nashwaak Granite

From Stop 1, continue north along the Nackawic Haulage Road. At 1.5 km from Stop 1, note the large roadcut on the right, just after the Keswick River Bridge. The roadcut consists of the red, medium-grained, equigranular, muscovite-bearing Hawkshaw Granite phase of the Pokiok Batholith. Continue north for 4.4 km, crossing the Nashwaak River. At 2.7 km past the Nashwaak River, turn left onto the Sisson Brook Road and continue along for 7.1 km. Turn left onto the logging road and proceed for 2.3 km, then turn south (left) at the intersection. Continue for about 300 m and stop at the outcrop exposed on both sides of the road. Walk north along the road to examine the outcrop that is exposed at intervals along the road.

The more southerly outcrop on the east side of the logging road (Fig. 3) is granite of the Nashwaak pluton containing foliated gabbroic xenoliths. Orientation of the foliation in separate xenoliths ranges from 40° to 130°, indicating that they have been rotated on incorporation into the granitic magma. The granite outcrop in the roadbed at this location contains a prominent vertical joint set striking 125°. The more northerly outcrop on the west side of the logging road is also granite of the Nashwaak pluton and contains a weak foliation striking about 030°.

Gabbroic xenoliths in the granite are unfoliated (Fig. 12). The granite in an exposure farther off the road also appears unfoliated. Other exposures on either side of the road contain a mixture of foliated granodiorite and gabbroic xenoliths in various stages of assimilation (Fig. 13).

Table 3. Average values for geochemistry, grain size, pebble texture, and pebble lithology of ablation till and basal till sites within 3 km of Stop 1.

Geochemistry Ablation till average (n = 3) Basal till average (n = 9)		
Element		
Ag (ppm)	<0.4	<0.4
As (ppm)	11.2	23.7
Au (ppb)	<2	3
Ca (wt %)	1.13	0.76
Cu (ppm)	22	35
Fe (wt %)	3.36	4.53
Mn (ppm)	1047	819
Na (wt %)	1.79	1.47
Pb (ppm)	21	26
Rb (ppm)	83	121
Sb (ppm)	1.4	1.9
Sr (ppm)	138	110
Th (ppm)	24.2	22.2
U (ppm)	8.4	5.7
V (ppm)	81	108
Zn (ppm)	61	83

Texture and Pebble Lithology Ablation till average (n = 2) Basal till average (n = 9)		
Grain Size		
gravel (%)	55	25
sand (% in matrix)	81	55
clay (% in matrix)	3	21
Texture	(n = 3)	(n = 9)
from	gSCL	gSL
to	vgSL	vgSL
Lithology	(n = 3)	(n = 9)
granitic (%)	51.5	27.5
gabbroic (%)	8.3	10.9
volcanic (%)	16.8	13.2
sedimentary (%)	22.5	46.4
quartz (%)	1.0	1.9

v = very **g** = gravelly **C** = clay
S = sandy **L** = loam

Stop 3: Howard Peak Granodiorite

From Stop 2, proceed north along the road for approximately 1.3 km. The outcrop is on the west side of the road.

Outcrops on the west side of the logging road (Fig. 3) consist of foliated granodiorite of the Howard Peak pluton. Foliation in the northerly part of the exposure strikes between 15° and 30° and dips about 80°SE. Granitic dykelets strike 175° and dip 80°E (Fig. 14). Quartz veins from 0.5 cm to 1 cm in width strike between 130° and 140° and dip 65°SW. The quartz veins cross-cut the foliation and dextrally offset the granitic dykelets.

Blebs of molybdenite are locally present in the quartz veins. Granitic dykelets in the southerly part of the exposure are overprinted by the foliation and are folded; however, a pod of granite pegmatite is undeformed (Fig. 15).

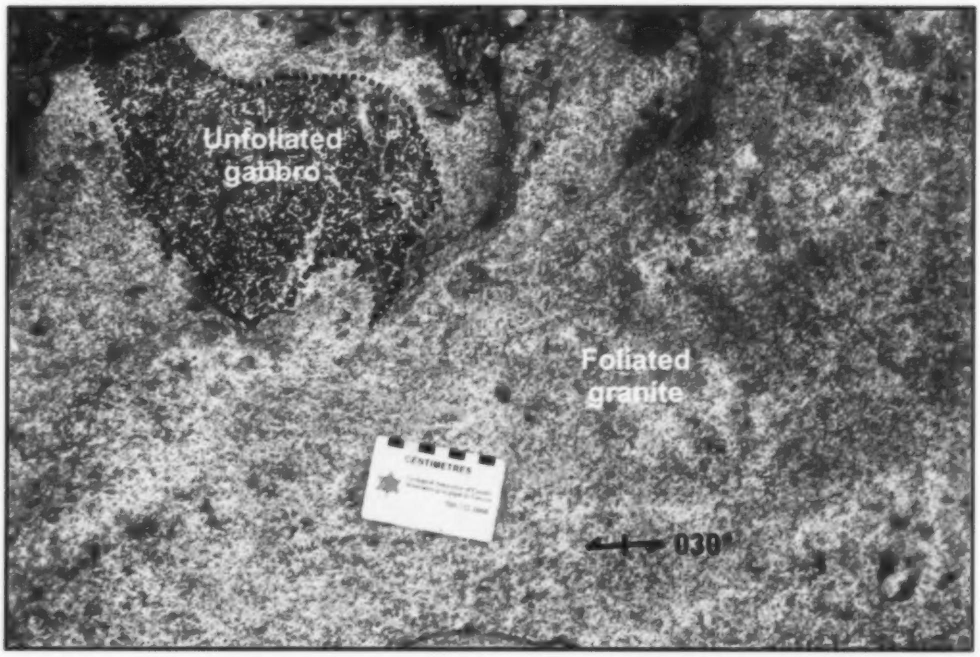
Unfoliated gabbro
Foliated granite
CENTIMETRES
030°

Figure 12. Outcrop of weakly foliated granite containing a partially assimilated, unfoliated gabbroic xenolith on the west side of the road at Stop 2 (scale in centimetres).

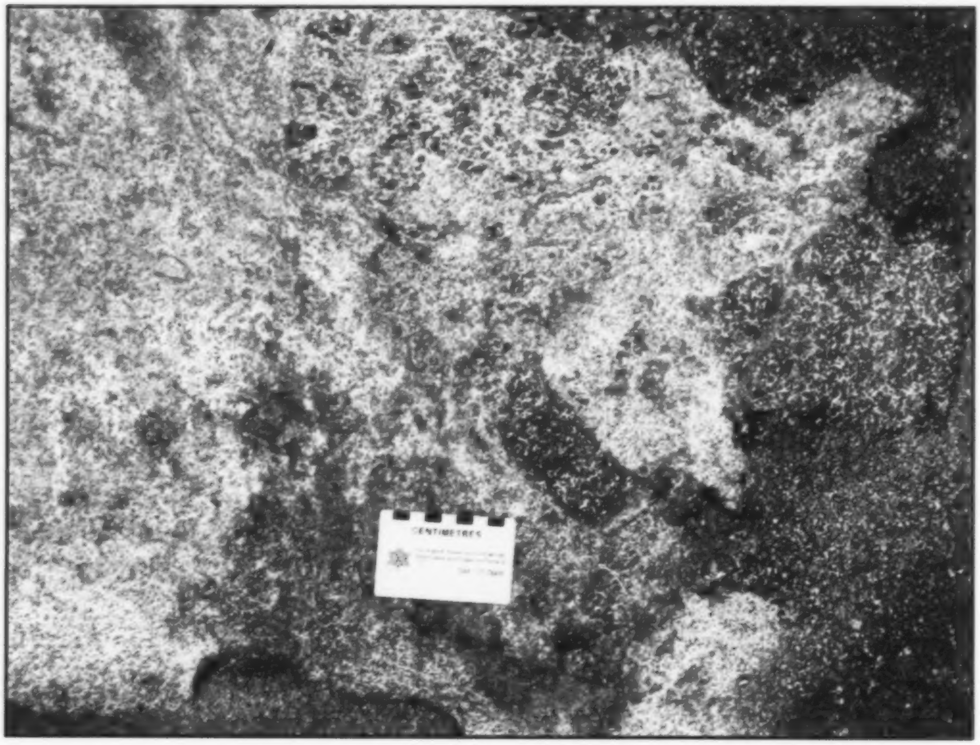
CENTIMETRES

Figure 13. Outcrop of variously assimilated gabbroic xenoliths within the granite at Stop 2. The xenolith foliations display differing orientations, suggesting that the xenoliths were rotated to their present position (scale in centimetres).

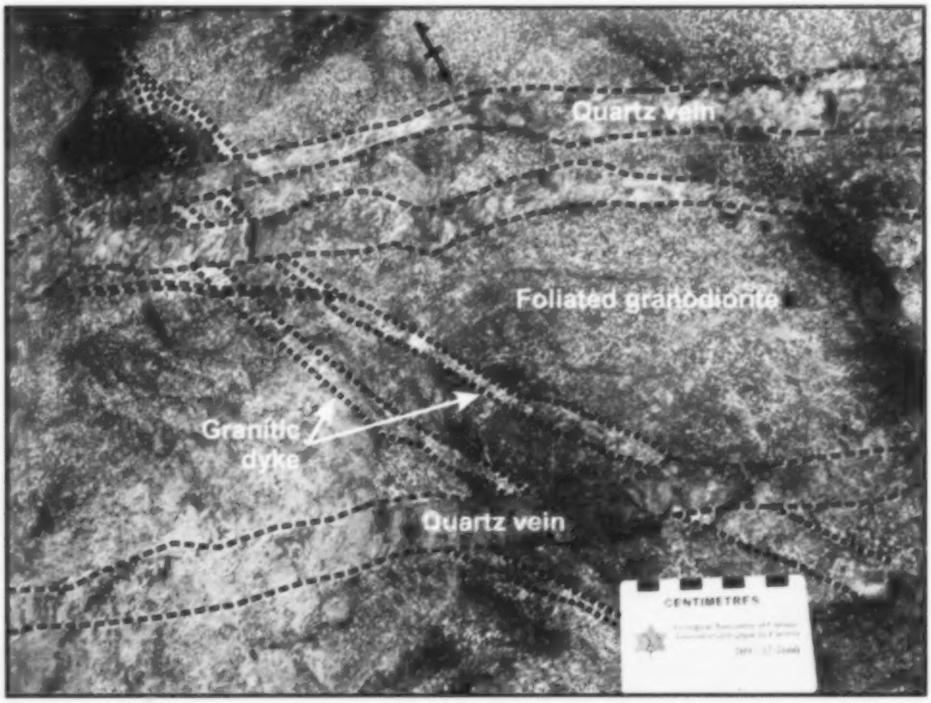
Quartz vein
Foliated granodiorite
Granitic dyke
Quartz vein
CENTIMETRES

Figure 14. Outcrop of foliated granodiorite at Stop 3, cross-cut by northerly trending granitic dykelets (blue dotted lines), which in turn are cross-cut by west-northwesterly trending, molybdenite-bearing quartz veins (red dotted lines).

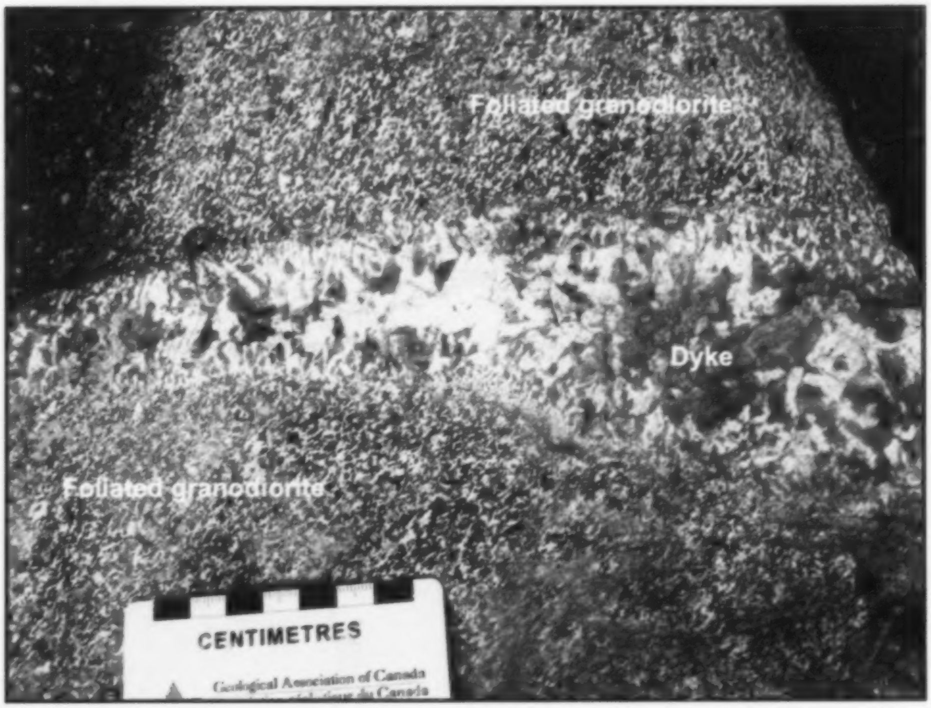
Foliated granodiorite
Dyke
Foliated granodiorite
CENTIMETRES
Geological Association of Canada

Figure 15. Foliated granodiorite at Stop 3, cross-cut by a granite pegmatite dyke.

Stop 4: Sisson Brook Zone III Trench

From Stop 3, continue north for about 800 m. Stop at the large trench on the east side of the road.

Hazards: The trench is very deep and has abundant loose rubble along the side. Please use extreme caution in the vicinity of the trench.

This trench (Fig. 3, 16) contains one of the best glacial stratigraphic sections in New Brunswick. Exposed only at the far western end of the trench is a remnant of an Early Wisconsinan basal lodgement till (Fig. 17). The till was deposited during the early Caledonia Phase by an east-southeast-flowing glacier. It is characterized by a comparatively high clay content (it is a sandy clay loam); abundant weathered granite and metasedimentary clasts; and anomalous levels for 18 elements (Table 4) that represent both distal (granitic) and proximal sources (Seaman and McCoy 2008).

Elsewhere in the trench, the bedrock surface is overlain by a Late Wisconsinan basal lodgement till. A fabric measurement of the till suggests emplacement by a south-southwesterly glacial flow, a trend known from regional cross-cutting striae to have prevailed during the middle part of the Late Wisconsinan (Scotian Phase). This till, a sandy loam, is coarser than the Early Wisconsinan till and is anomalous in nine elements (Table 4), representing mineralization in the underlying bedrock (Seaman and McCoy 2008).

The Scotian Phase till is blanketed by approximately 1 m to 2.5 m of Younger Dryas (Collins Pond Phase) till, formed during a brief cold period at the very end of the Late Wisconsinan that saw the reactivation or regrowth of glaciers. This Younger Dryas till was deposited by westerly flowing ice from the Gaspereau Ice Centre. It is a sandy loam to loamy sand, formed in part by reworking of Late Wisconsinan glaciofluvial and glaciolacustrine deposits (Fig. 18). The Younger Dryas till effectively masks much of the mineralization represented in the middle and lower tills; only tin and tungsten show anomalous levels (Table 4). This masking effect highlights the caution needed when evaluating the results of till and soil sampling at shallow depths. Evidently, the absence of a surficial anomaly does not rule out the presence of mineralized bedrock at depth (Seaman and McCoy 2008).

The thickness of Younger Dryas till at this site clearly illustrates that deposit thickness is no indicator of length of time needed for till formation. Radiocarbon dates on two samples from this till indicate its formation at the beginning of the Younger Dryas, while a similar date on basal peat from a surface depression shows that the site was deglaciated within about 400 years (Seaman and McCoy 2008).

Bedrock at the eastern end of the trench is a fine-grained silicified gabbro that possesses a prominent foliation trending 003° and dipping 55°W. Chalcopyrite and pyrite are present in 10 cm thick silicified zones and quartz veins that follow the foliation trend. A later set of quartz veins (about 2 cm thick), striking 125° and dipping 80°SW, transects the foliation in the gabbro

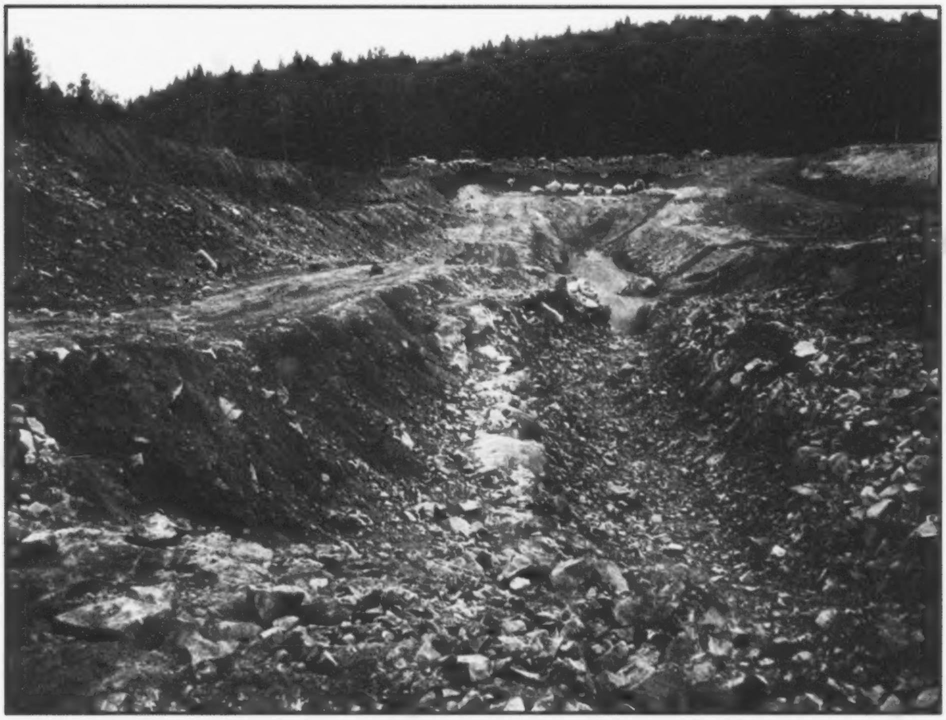

Figure 16. Exploration trench exposing Zone III of the Sisson Brook deposit at Stop 4. View looking west; truck and bulldozer for scale.

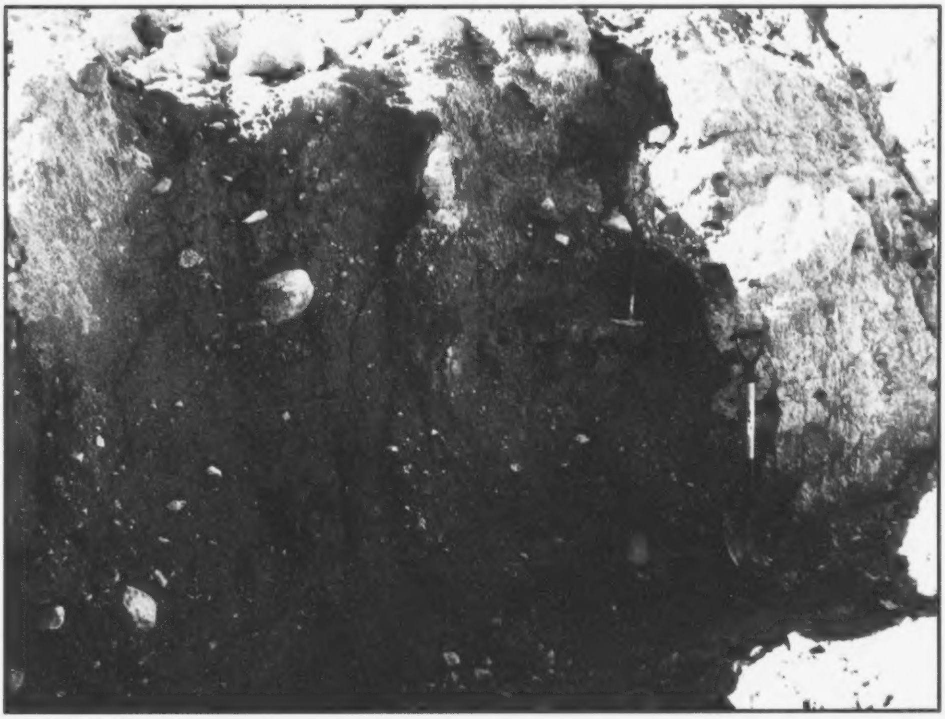

Figure 17. Early Wisconsinan basal lodgement till in the western section of the trench at Zone III at Stop 4. Hammer and shovel for scale.

Table 4. Average geochemical and grain size values for the three tills at Sisson Brook (from Seaman and McCoy 2008). Anomalous = ≥4 standard deviation above mean regional background value.

	Upper Till (n = 6)			**Middle Till** (n = 9)			**Lower Till** (n = 3)		
Element	min	avg	max	min	avg	max	min	avg	max
Ag (ppm)	<0.3	0.3	0.5	<0.3	0.5	1.0	0.4	0.5	0.6
As (ppm)	7.1	17.5	21.6	30.5	45.0	56.7	33.8	46.5	54.5
Au (ppb)	<2	<2	<2	<2	2	6	<2	4	9
Ba (ppm)	170	497	640	<50	564	780	840	860	890
Bi (ppm)	1.1	2.1	4.7	5.8	12.7	23.7	10.1	14.0	19.4
Ca (wt %)	0.32	0.56	0.74	0.58	0.92	1.41	1.01	1.11	1.22
Cd (ppm)	<0.3	0.3	0.5	0.5	0.7	1.2	0.6	0.6	0.7
Co (ppm)	13	15	16	12	19	28	19	19	19
Cs (ppm)	9	11	13	12	19	34	16	18	20
Cu (ppm)	24	32	51	66	191	528	116	134	147
Fe (ppm)	3.09	3.47	3.83	3.74	6.12	16.10	4.89	5.10	5.39
Hg (ppb)	11	13	15	9	14	20	<5	6	8
In (ppm)	<0.2	<0.2	<0.2	<0.2	0.3	1.3	0.2	0.3	0.3
Mn (ppm)	477	642	776	599	987	1340	911	1054	1180
Mo (ppm)	<1	<1	2	<1	36	260	<1	<1	<1
Ni (ppm)	36	43	48	34	42	51	24	27	29
Pb (ppm)	17	20	23	27	43	86	39	46	50
Rb (ppm)	120	137	156	144	186	271	228	251	285
S (wt %)	<0.01	<0.01	<0.01	<0.01	0.02	0.11	<0.01	<0.01	<0.01
Sb (ppm)	0.8	1.1	1.4	1.1	1.7	2.2	1.3	1.5	1.6
Sn (ppm)	4	6	9	6	11	19	12	13	15
Th (ppm)	20.6	22.7	24.7	19.1	23.8	27.9	38.7	39.7	41.6
U (ppm)	7.0	8.9	10.0	6.5	8.0	10.3	11.0	12.4	14.4
W (ppm)	<1	11	38	18	285	1240	29	39	49
Zn (ppm)	73	85	93	109	149	218	137	151	161
REEs									
Y (ppm)	12	33	53	18	27	42	40	45	48
La (ppm)	50.7	55.8	68.8	43.1	57.6	65.8	89.1	93.4	96.1
Ce (ppm)	106	113	125	112	119	137	175	180	190
Nd (ppm)	37	44	60	33	44	52	65	67	69
Sm (ppm)	7.7	8.9	10.7	6.6	8.9	9.7	13.4	13.8	14.1
Eu (ppm)	1.5	1.8	2.4	1.3	1.8	2.1	2.6	2.6	2.7
Tb (ppm)	<0.5	1.2	1.7	<0.5	0.8	1.6	<0.5	1.3	1.8
Yb (ppm)	4.8	5.8	7.0	4.1	5.5	6.7	6.1	6.2	6.2
Lu (ppm)	0.75	1.00	1.13	0.75	0.97	1.08	1.10	1.13	1.17
Grain Size (of matrix)									
Sand (%)	57	68	80	62	71	82	54	55	57
Silt (%)	14	23	30	13	20	28	18	19	19
Clay (%)	4	10	15	4	9	16	24	26	28
Legend	Threshold anomalous			Anomalous			Very anomalous		

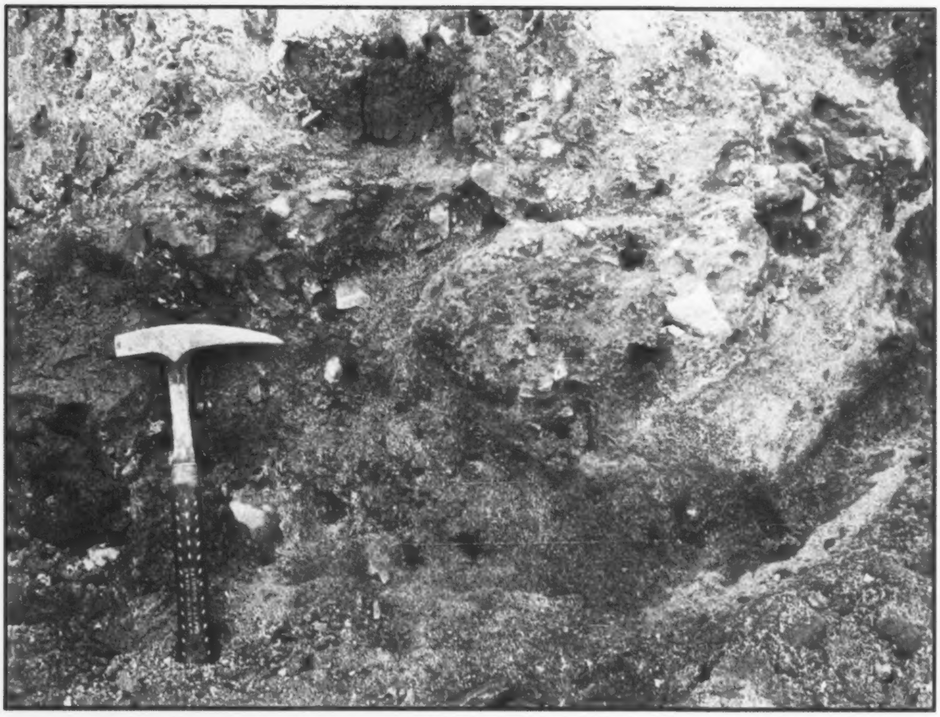

Figure 18. Sandy loam to loamy sand of the Younger Dryas till, exposed in the trench at Zone III , Sisson Brook deposit. Hammer for scale.

and contains abundant molybdenite. Westward along the south wall of the trench, a 2 cm thick quartz vein with a 095° strike and 60°S dip is intersected at a low angle by a 4 cm thick quartz vein with a 135° strike and 85°SW dip. In places, the veins are sinistrally offset by a few centimetres along the northerly trending foliation plane (Fig. 9). Granitic dykes from 10 cm to 15 cm thick cut the gabbro and possess a strong northerly trending, cataclastic foliation along which feldspar augen are aligned. The top of the north wall of the trench features a strongly foliated, fine-grained gabbro containing plagioclase porphyroclasts about 2 cm in length (Fig. 8). The gabbro is cut by a vertical, northerly trending granite pegmatite dyke that is about 5 cm thick and cut by two intersecting, molybdenite-bearing quartz veins. The earlier quartz vein (V_1) is about 0.5 cm to 1 cm thick, strikes 110°, and dips 65°SW; the later quartz vein (V_2) is about 2 cm thick, strikes 140°, and dips 60°SW (Fig. 19).

Stop 5: Sisson Brook Zone I Trench

From Stop 4, proceed 500 m to the intersection and turn right onto Sisson Brook Road. Stop 5 is located 300 m from the intersection on the north (left) side of the road.

Hazards: Smooth surfaces on the outcrop may be slippery when wet.

The bedrock in the northeastern part of the trench at Zone I (Fig. 3) comprises an interbedded sequence of dark grey siltstone and light grey felsic tuff of the Turnbull Mountain Formation (Fig. 20). The beds range from 1 cm to 10 cm in thickness, strike 020°, and dip 65°E. The bedded sequence is in contact with granodioritic rocks of the Howard Peak pluton along a

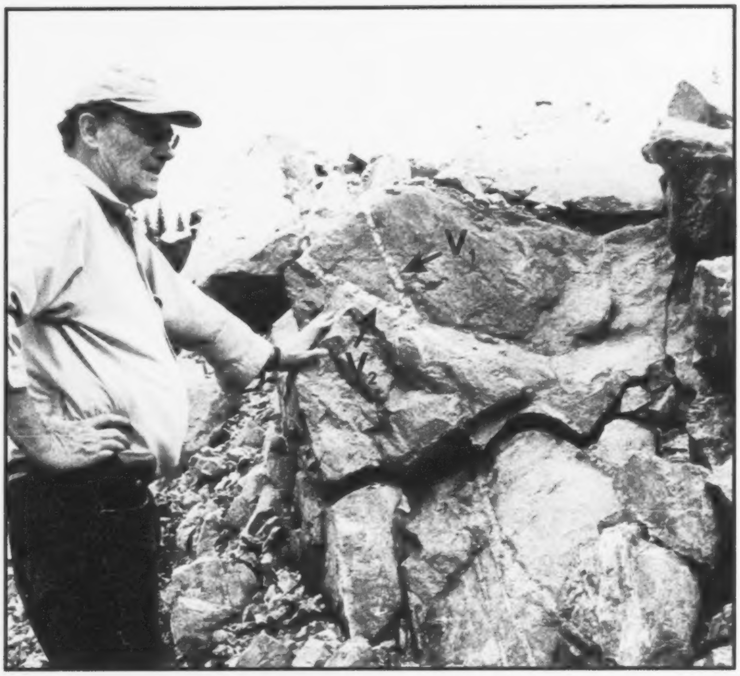

Figure 19. Intersecting, molybdenite-bearing quartz veins in the Zone III trench at Stop 4, Sisson Brook deposit. View looking east.

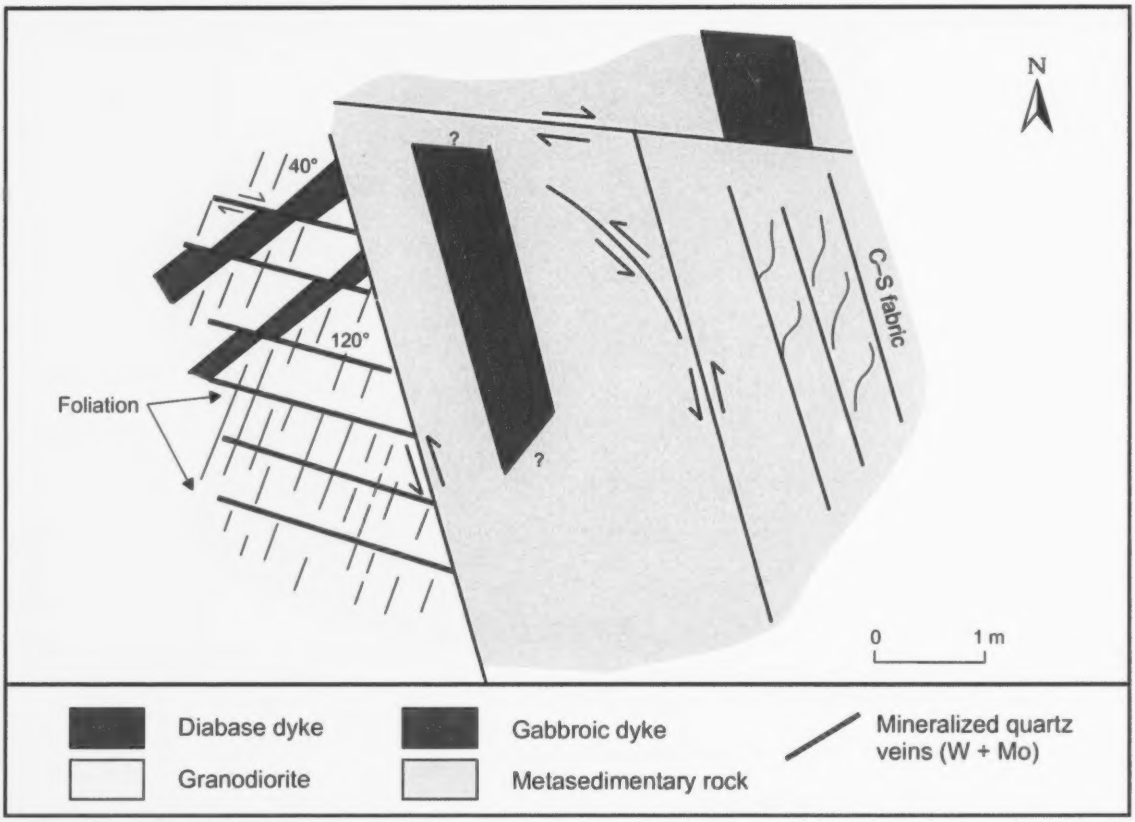
N
40°
120°
Foliation
?
?
C–S fabric
0
1 m
Diabase dyke
Gabbroic dyke
Mineralized quartz veins (W + Mo)
Granodiorite
Metasedimentary rock

Figure 20. Schematic geology map of the trench at Zone I, Sisson Brook deposit. Figure 3 shows the approximate trench location.

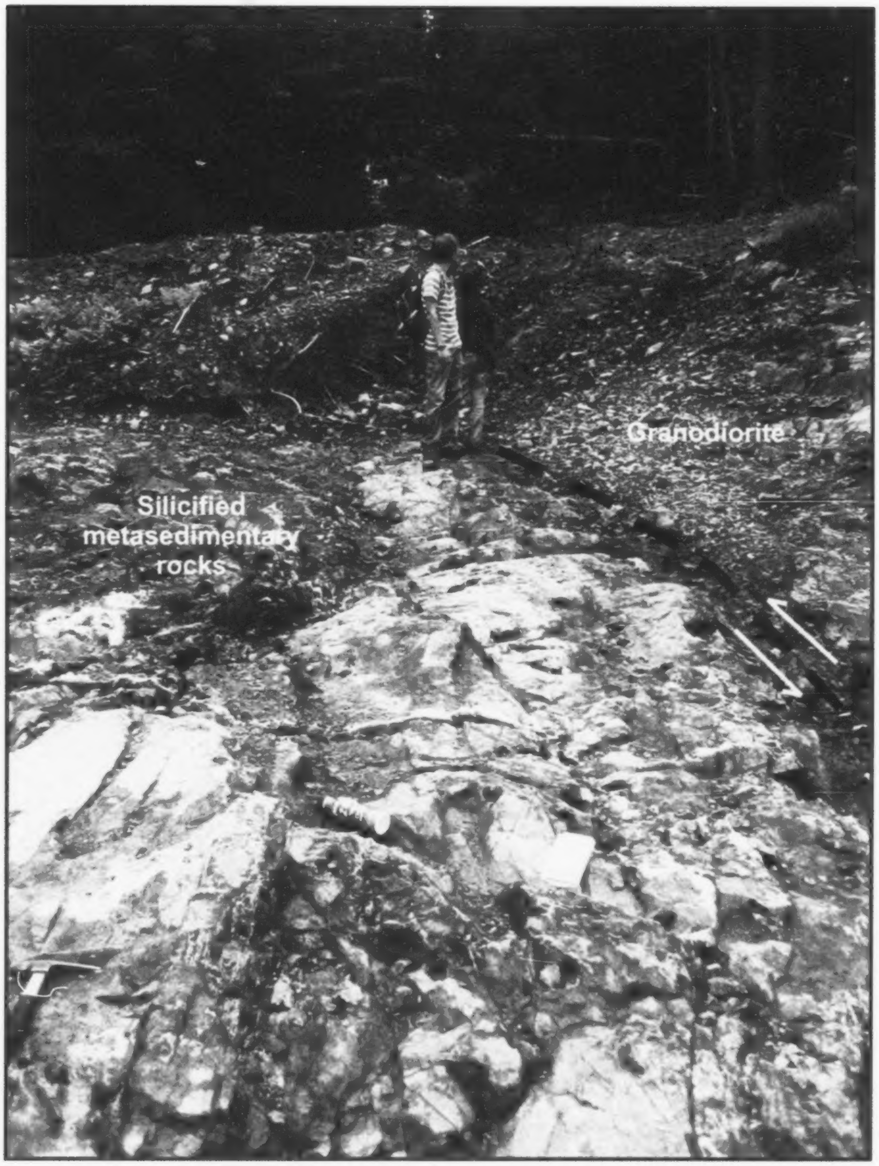

Figure 21. Faulted contact between metasedimentary rocks and granodiorite in the trench at Zone I, Stop 5, Sisson Brook deposit. View looking southwest.

north-northwesterly trending fault exposed in the southwestern part of the trench. A medium-grained, north-northwesterly trending dyke intrudes the bedded sequence in the northern part of the trench and is truncated to the south by an east–west-trending cross-fault. Movement on this cross-fault was dextral, assuming that the gabbroic dyke observed on the southern side of the fault represents the displaced continuance of the same dyke.

Granodiorite of the Howard Peak pluton shows a steep foliation that strikes about 030°. Both the foliation and a prominent, west-northwesterly trending (300°–310°) joint set in the granodiorite are abruptly truncated by the north-northwesterly trending fault that marks the boundary with the bedded rocks to the northeast (Fig. 20, 21). Schistosity–shear fabrics in the

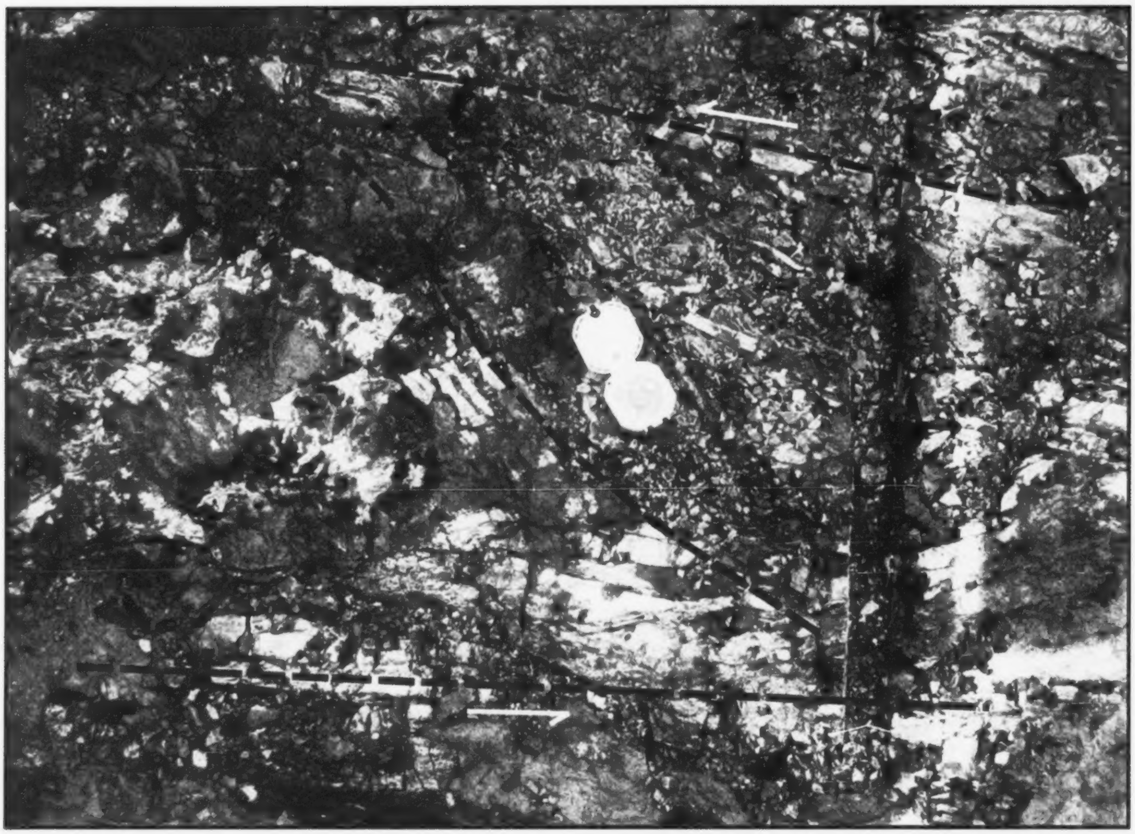

Figure 22. C–S fabric developed in silicified metasedimentary units in the trench at Zone I, Sisson Brook deposit. View looking northwest.

bedded sequence indicate sinistral movement along this fault zone (Fig. 22). Some movement also took place along the west-northwesterly trending joint set, as indicated by small dextral displacement of the margins of two 30 cm thick, northeasterly trending diabase dykes cutting the granodiorite (Fig. 7, 20). Narrow quartz veins containing pyrite, chalcopyrite, wolframite, and molybdenite follow the strike of bedding, the fault zone, and the joint set. The fault zone exposed in the trench at Zone I is interpreted to be a horsetail splay off the main north-northeasterly trending, high-strain shear zone that lies along the eastern margin of the Howard Peak pluton in Zone III.

PART 2: MOUNT PLEASANT SN–W–MO–BI–IN DEPOSIT

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TREVOR BOYD [3], AND GUSTAAF J.A. KOOIMAN [3]

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[2] Natural Resources Canada, 601 Booth Street, Ottawa, Ontario, CANADA K1A 0E8
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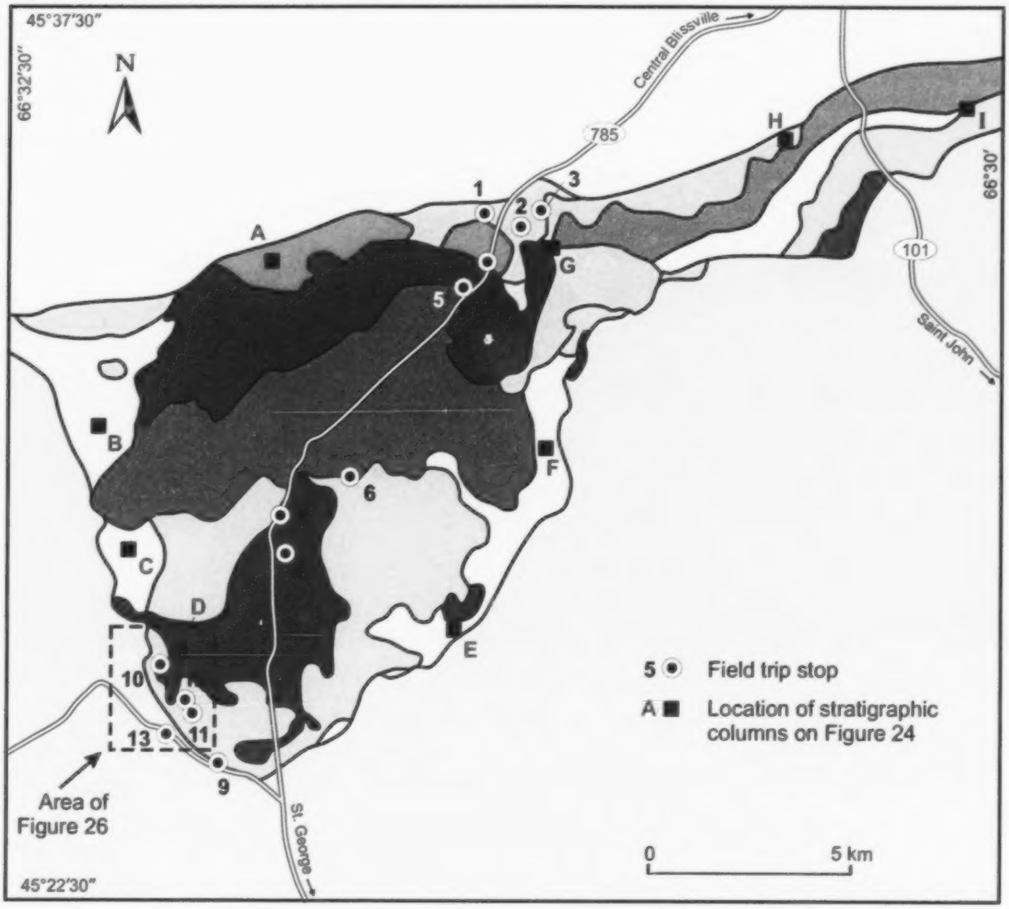
INTRODUCTION

The Mount Pleasant Sn–W–Mo–Bi–In deposit is situated in the McDougall Lake map area (NTS 21 G/07) of southwestern New Brunswick (Fig. 1). The deposit is hosted by the Late Devonian Mount Pleasant Caldera Complex (McCutcheon et al. 1997) along the northern margin of the Late Silurian to Late Devonian Saint George Batholith (Fig. 2). The caldera complex is an elliptical feature that underlies an area of approximately 13 km by 34 km, as outlined by regional gravity and magnetic maps. It overlies pre-caldera (Ordovician and Silurian) sedimentary rocks of the Cookson and Kingsclear groups to the east and west, and is overlain by Carboniferous (Pennsylvanian) conglomerate and sandstone to the north (Fig. 23).

McCutcheon et al. (1997) propose that the Mount Pleasant Caldera Complex developed in an epicontinental setting, possibly in response to basaltic underplating and the resulting lithospheric thinning. They suggest that it evolved through a process of caldera collapse followed by several stages involving hiatuses in volcanic activity, repeated establishment of a high-level and zoned magma chamber, and resurgence. Each stage in the caldera's development allowed tapping of magmas from various levels in the system, as evidenced by chemical and mineralogical features. According to McCutcheon et al. (1997), the foregoing features indicate that 1) the basalt units were mantle-derived from underplated material, 2) the andesitic volcanic rocks were likely a product of assimilation and fractional crystallization of basalt and crustal contaminants, and 3) the felsic units were derived from parts of the fractionating, high-level and zoned magma chamber.

GEOLOGICAL SETTING

Rocks within the Mount Pleasant Caldera Complex are divided into the Exocaldera, Intracaldera, and Late Caldera-Fill sequences (Fig. 23; McCutcheon et al. 1997). These sequences are subdivided into formations and members of the Late Devonian Piskahegan Group and associated subvolcanic intrusions (Fig. 24). Comprehensive descriptions of the caldera complex, associated mineral deposits, and metallogenic models are presented in numerous references (van de Poll 1967; Parrish and Tully 1978; Kooiman et al. 1986; Sinclair et al. 1988, 2006; Samson 1990; McCutcheon et al. 1997, 2001; Yang et al. 2003, 2008; Inverno and Hutchinson 2004, 2006) and are summarized in the following sections.


45°37'30"
66°32'30"
N
Central Blissville
785
1
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3
A
H
I
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66°30'
101
Saint John
B
F
6
C
D
E
10
11
13
9
Area of Figure 26
St. George
45°22'30"
5 ● Field trip stop
A ■ Location of stratigraphic columns on Figure 24
0
5 km

Figure 23. Geology of the Mount Pleasant Caldera Complex (see Fig. 2). Legend on facing page.

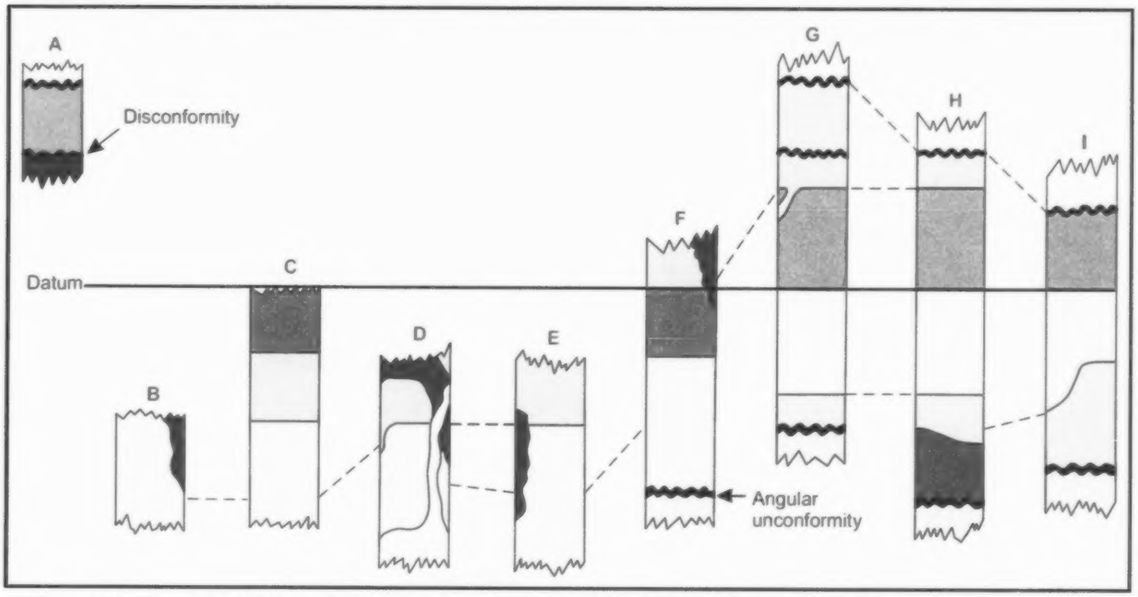

A
Disconformity
G
H
I
F
C
Datum
D
E
B
Angular unconformity

Figure 24. Representative stratigraphic columns of the Mount Pleasant Caldera Complex. Column locations appear as squares on Figure 23, above. Legend on facing page.

☐ **CARBONIFEROUS**

LATE DEVONIAN

Late Caldera-Fill Sequence

☐ Mount Pleasant Granitic Suite (on Fig. 24 only)
☐ Kleef Formation
▨ Big Scott Mountain Formation

Intracaldera Sequence

■ McDougall Brook Granite
■ Seelys Formation
☐ Little Mount Pleasant Formation
☐ Scoullar Mountain Formation

Exocaldera Sequence

☐ Bailey Rock Rhyolite
■ Carrow Formation
☐ South Oromocto Andesite
☐ Rothea Formation
■ Hoyt Station Basalt

ORDOVICIAN–EARLY DEVONIAN

☐ Pre-caldera rocks

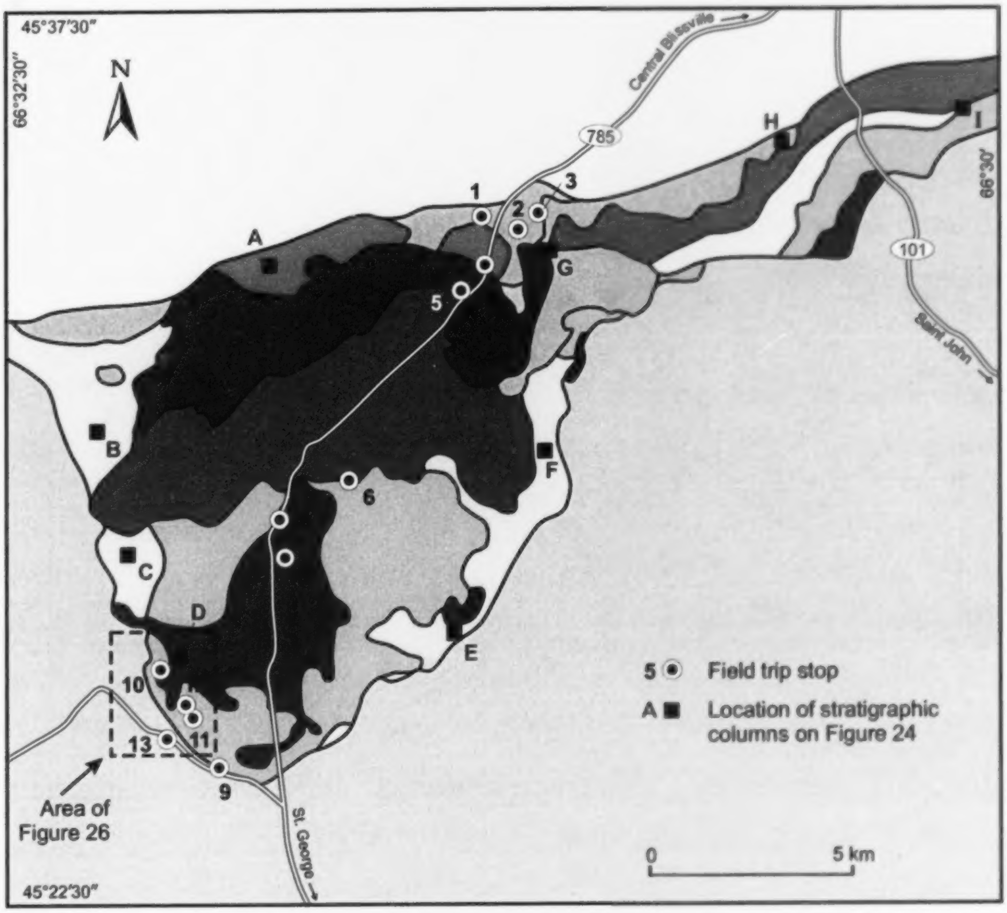
Figures 23 and 24 *(cont'd)*. Legend for figures on facing page, both of which are modified from McCutcheon et al. (1997).

Exocaldera Sequence

The Exocaldera Sequence consists, in ascending stratigraphic order, of the Hoyt Station Basalt, Rothea Formation, South Oromocto Andesite, Carrow Formation, and Bailey Rock Rhyolite.

The *Hoyt Station Basalt* comprises at least two flow units. Minor pebble to cobble conglomerate and lithic lapilli tuff is associated with this basalt. The *Rothea Formation* includes a lower member consisting of unwelded but compacted pumiceous lapilli tuff and crystal tuff units; a middle member that grades from nearly aphyric tuff at the base to crystal tuff at the top (pyroxene(?) pseudomorphs typify this unit); and an upper member consisting of a lower fine-grained redbed unit and an upper lithic tuff unit. The *South Oromocto Andesite* is composed of at least three flow units, the basal flow being the most areally extensive and the only one to exhibit porphyritic textures. Calcite veins and hematite bands near the top reflect degassing of the flow interior.

The *Carrow Formation* is predominantly a fining-upward redbed sequence that grades from pebble to cobble conglomerate at the base to mudstone with intercalated calcrete at the top. Toward the southwest, the conglomerate contains abundant clasts of the Seelys (Intracaldera Sequence) and Rothea formations, but to the northeast, metasedimentary clasts predominate. In the lower part of the Carrow Formation, an unwelded but highly compacted pumiceous lapilli tuff contains abundant pumice fragments. Locally, a basalt and basalt-clast mudflow occurs near the top of the formation. A spore assemblage from the upper part of the Carrow Formation has yielded a precise Late Famennian age (McGregor and McCutcheon 1988).


45°37'30"
66°32'30"
N
Central Blissville
785
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H
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66°30'
101
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Saint John
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D
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10
11
13
9
Area of Figure 26
St. George
45°22'30"
5 ⦿ Field trip stop
A ■ Location of stratigraphic columns on Figure 24
0
5 km

Figure 23. Geology of the Mount Pleasant Caldera Complex (see Fig. 2). Legend on facing page.

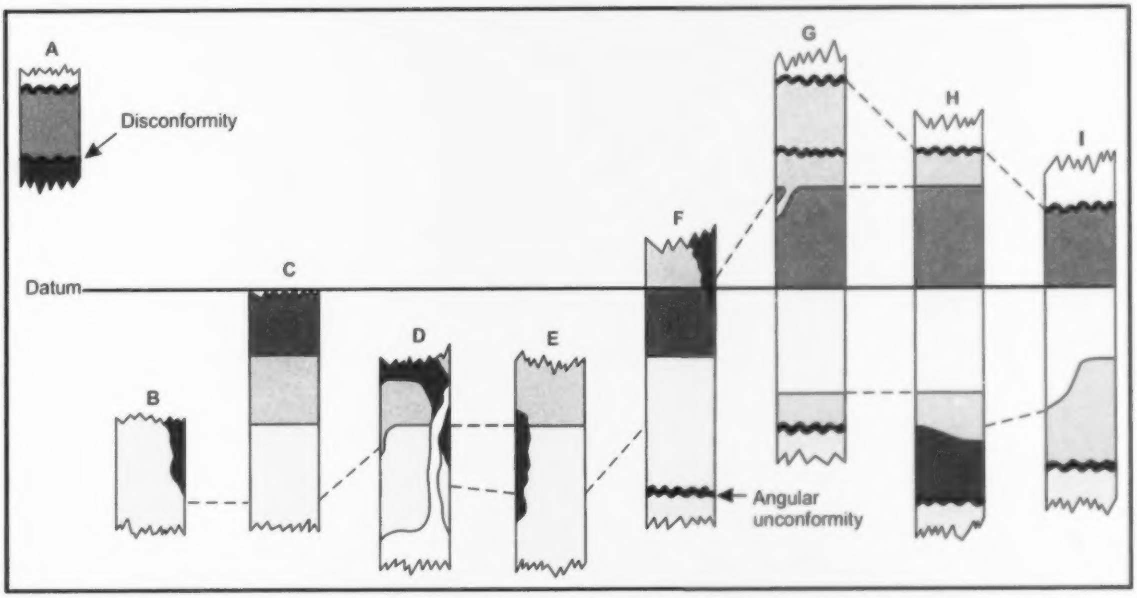
A
Disconformity
G
H
I
F
C
Datum
D
E
B
Angular unconformity

Figure 24. Representative stratigraphic columns of the Mount Pleasant Caldera Complex. Column locations appear as squares on Figure 23, above. Legend on facing page.

☐ **CARBONIFEROUS**

LATE DEVONIAN

Late Caldera-Fill Sequence

☐ Mount Pleasant Granitic Suite (on Fig. 24 only)
░ Kleef Formation
▒ Big Scott Mountain Formation

Intracaldera Sequence

■ McDougall Brook Granite
■ Seelys Formation
░ Little Mount Pleasant Formation
☐ Scoullar Mountain Formation

Exocaldera Sequence

░ Bailey Rock Rhyolite
■ Carrow Formation
☐ South Oromocto Andesite
░ Rothea Formation
■ Hoyt Station Basalt

ORDOVICIAN–EARLY DEVONIAN

░ Pre-caldera rocks

Figures 23 and 24 *(cont'd).* Legend for figures on facing page, both of which are modified from McCutcheon et al. (1997).

Exocaldera Sequence

The Exocaldera Sequence consists, in ascending stratigraphic order, of the Hoyt Station Basalt, Rothea Formation, South Oromocto Andesite, Carrow Formation, and Bailey Rock Rhyolite.

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The *Carrow Formation* is predominantly a fining-upward redbed sequence that grades from pebble to cobble conglomerate at the base to mudstone with intercalated calcrete at the top. Toward the southwest, the conglomerate contains abundant clasts of the Seelys (Intracaldera Sequence) and Rothea formations, but to the northeast, metasedimentary clasts predominate. In the lower part of the Carrow Formation, an unwelded but highly compacted pumiceous lapilli tuff contains abundant pumice fragments. Locally, a basalt and basalt-clast mudflow occurs near the top of the formation. A spore assemblage from the upper part of the Carrow Formation has yielded a precise Late Famennian age (McGregor and McCutcheon 1988).

The *Bailey Rock Rhyolite* is a porphyritic lava and, as such, is characterized by an absence of angular crystal fragments and pumice pseudomorphs. This rhyolite is unique in that it intrudes the boundary between the Exocaldera and Intracaldera sequences. A saprolite separates the Bailey Rock Rhyolite from the overlying Late Caldera-Fill Sequence.

Intracaldera Sequence

The Intracaldera Sequence comprises, in ascending stratigraphic order, the Scoullar Mountain Formation, Little Mount Pleasant Formation, Seelys Formation, and McDougall Brook Granitic Suite. Additionally, it includes felsic dykes and one mafic dyke that intrude the Scoullar Mountain and Little Mount Pleasant formations, respectively.

The *Scoullar Mountain Formation* is characterized by sedimentary breccia and interbedded andesitic lavas. Felsic pyroclastic rocks are voluminous in places, and one sandstone–conglomerate unit is present. The sedimentary breccia is dominated by angular pebble to boulder metasedimentary clasts, and a few undeformed crystal tuff clasts that contain ~1% altered biotite. A pumiceous lapilli tuff near the apparent top has ~1% amphibole and accessory apatite. The *Little Mount Pleasant Formation* is composed of crystal tuff and massive porphyritic rhyolite. The crystal tuff is characterized by unflattened to weakly flattened, microcrystalline, recrystallized pumice fragments and chloritized amphibole with associated apatite. Phenocrysts inside the recrystallized pumice fragments are an order of magnitude larger than those outside, indicating that significant mechanical breakage of phenocrysts occurred during eruption. The *Seelys Formation* consists of lithic tuffs and pumice-bearing lithic lapilli tuffs, banded and pumiceous crystal tuff, and densely welded crystal tuff. The basal part contains clasts of the Scoullar Mountain Formation (andesite) and Little Mount Pleasant Formation. Quartz and feldspar phenocrysts increase in size and abundance from base to top in the upper part of the sequence. Platy biotite is virtually absent, but metamict zircon is a common accessory in all units.

The *McDougall Brook Granitic Suite* comprises a border phase of feldspar porphyry (MBG1); a main-phase core of porphyritic monzogranite containing large quartz and feldspar phenocrysts (MBG2); and equigranular to subporphyritic quartz monzonite (MBG3). The main ferromagnesian mineral phase is chloritized amphibole with associated apatite. The fine-grained groundmass of the porphyry (MBG1), as well as the size and abundance of feldspar phenocrysts, increases inward away from contact with the country rock. Hydrothermal breccias occur locally where McDougall Brook granitic rocks occur in proximity to the country rock.

The relative stratigraphic position of units in the Exocaldera and Intracaldera sequences is based on the following observations:

- The upper part of the Rothea Formation consistently contains ~1% platy biotite pseudomorphs. The only intracaldera rocks with this much biotite are volcanic clasts within sedimentary breccia of, and a tuff unit near the apparent base of, the Scoullar Mountain Formation.

- Andesitic rocks occur in only two units: the South Oromocto Andesite of the Exocaldera Sequence and the Scoullar Mountain Formation of the Intracaldera Sequence.

- The Carrow Formation contains clasts of the Seelys Formation.

- The Bailey Rock Rhyolite, which occurs in both sequences, intrudes and/or overlies the Carrow Formation but is intruded by, or grades into, McDougall Brook granitic rocks.

Late Caldera-Fill Sequence

The Late Caldera-Fill Sequence includes the Big Scott Mountain Formation, the Kleef Formation, and the Mount Pleasant Granitic Suite with its associated breccias and felsic dykes (Fig. 23, 24). Although ages of the Late Caldera-Fill rocks are not firmly established, they most likely are Late Devonian but could range into Mississippian.

The Big Scott Mountain Formation consists of porphyritic to nearly aphyric rhyolite, lithic tuff to lithic lapilli tuff, and crystal tuff. Most of the rhyolites are characterized by pyroxene(?) pseudomorphs. One of the rhyolite units appears to disconformably overlie rocks of the McDougall Brook Granitic Suite. The lithic tuffs contain clasts that were derived from the Seelys Formation, McDougall Brook suite, and aphyric rhyolite of uncertain correlation. Primary layering is discernible in the crystal tuff and is defined by slight differences in crystal size and abundance.

The *Kleef Formation* includes redbeds, porphyritic to glomeroporphyritic basalt, and pumiceous lithic tuff to lithic lapilli tuff. Pebble to cobble conglomerate contains clasts of the Scoullar Mountain and Seelys formations, plus ones from the Bailey Rock Rhyolite and Big Scott Mountain Formation. The basalt is characterized by large plagioclase phenocrysts (up to 2 cm) and, near the top of the unit, some plagioclase glomerocrysts (up to several centimetres). The lithic tuffs are characterized by their reddish brown coloration and abundant fossil pumice.

The *Mount Pleasant Granitic Suite* occurs in surface exposures as granitic dykes and small plug-like bodies associated with magmatic to hydrothermal breccias (Fig. 23, 24), as defined by Sillitoe (1985). The dykes commonly exhibit flow layering, and cross-cutting relationships among the dykes indicate multiple stages of intrusion. Two types of hydrothermal breccia are present: an older and more voluminous felsic phase, and a younger chloritic phase (Kooiman et al. 1986). The dykes, small plugs, and associated breccia, together with related subvolcanic granitic intrusions at depth (Granites I to III), were emplaced along the western margin of the caldera complex (Fig. 25).

Petrochemical studies and modelling of granitic systems in the caldera (Yang et al. 2003) indicate a direct link between the highly evolved granitic rocks (Granites I, II, III) and associated breccias of the Mount Pleasant Granitic Suite, and the less evolved rocks of the

McDougall Brook Granitic Suite. Specifically, these investigations suggest that all intrusions originated from the same parent magma through fractional crystallization and crustal contamination (Fig. 25). Subsequent compositional changes were likely controlled by extensive fluid fractionation within the Mount Pleasant Granitic Suite.

EXPLORATION HISTORY

The Mount Pleasant deposit was staked in 1954 by Geochemical Associates, following a regional geochemical survey for base metals. Subsequent diamond drilling by Selco Exploration Ltd. in 1955 and Kennco Exploration (Canada) Ltd. in 1956 was not encouraging, and the claims were allowed to lapse. Mount Pleasant Mines Ltd. restaked the property in 1959, and diamond drilling in 1960 outlined significant tin mineralization; an adit was developed between 1962 and 1965. Sullico Mines Ltd. (part of the Sullivan Mining Group) discovered tungsten–molybdenum mineralization at Mount Pleasant in 1969, and by 1976 it had outlined a number of orebodies and further developed the underground workings.

In 1977 Billiton Exploration of Canada Ltd. signed a joint venture with Brunswick Tin Mines Ltd. (owned 89% by Sullivan Mining Group and 11% by Mount Pleasant Mines Ltd.) to develop a mine at Mount Pleasant. About 1 Mt of tungsten ore was mined between 1983 and 1985, after which production ceased due to low metal prices. In 1985 Lac Minerals Ltd. drove two exploration drifts into the tin mineralization as part of a joint venture with Billiton.

Piskahegan Resources Ltd. undertook an assessment of the deposit's indium resources in 1993 after acquiring ownership of the property. Adex Mining Inc. assumed ownership in 1995. Adex completed definition drilling programs at Mount Pleasant in 2008 in order to upgrade ore reserve calculations for both the tungsten–molybdenum–bismuth-rich Fire Tower Zone and the tin–indium-rich North Zone. A series of metallurgical tests have been conducted to design and develop a pilot plant program in preparation for commercial production of tungsten, molybdenum, tin, indium, and zinc at Mount Pleasant.

DEPOSIT GEOLOGY

The Mount Pleasant deposit is associated with hydrothermal breccias and intrusive rocks of the Mount Pleasant Granitic Suite that cut the Intracaldera Sequence (Fig. 23, 26). The granitic phases and fluids producing mineralization were probably derived by in situ (noneruptive) cooling of peraluminous anorogenic magma by convective fractionation. By this process, the magma body solidifies from the margin to the centre of the magma chamber as the zone of solidification moves progressively inward (Rice 1981).

Mass balance calculations show that, under such conditions, small volumes (10–20 km^3) of magma with an initial composition resembling that of the Little Mount Pleasant Formation could yield quantities of metal and fluid capable of producing the mineralized zones at Mount Pleasant.

Mount Pleasant Granitic Suite

The contact relationships among, and distribution of, the various granitic phases that collectively comprise the Mount Pleasant Granitic Suite (Fig. 26, 27) were determined from drill cores and exposures in underground workings at Mount Pleasant. From oldest to youngest, these phases are designated as Granite I, Granite II, and Granite III and are interpreted to represent successive cooling stages of one magma body (Fig. 25).

Granite I occurs as irregular bodies closely associated with the hydrothermal breccias. Its contacts with the breccias are commonly gradational, and Granite I fragments are locally abundant within the breccias. In relatively unaltered specimens, Granite I is typically fine grained and equigranular. However, the textural features of Granite I are obscured in most areas by pervasive silicic and chloritic alteration.

Granite II gradationally underlies Granite I at depth, and dyke-like bodies of Granite II intrude Granite I and the overlying breccias. Banded porphyry dykes that crop out at surface are probably derived from Granite II. Granite II ranges from aplitic to porphyritic and locally contains abundant miarolitic cavities and comb quartz layers. The latter feature consists of parallel to subparallel layers in which quartz crystals are oriented approximately perpendicular to the planes of layering. This is one in a family of unidirectional solidification textures (USTs) associated with fluid-saturated and/or undercooled magmas.

Granite III forms a large body that gradationally underlies Granite II and locally intrudes both Granites I and II. The contacts are commonly sharp and in many places are marked by thin (0.5–2 cm wide) layers of USTs, mainly K-feldspar, in Granite III. Granite III ranges from fine to medium grained and can be equigranular porphyritic and pegmatitic. Miarolitic cavities filled with very fine-grained sericite are locally abundant.

The absolute age of the granitic rocks in the Mount Pleasant Granitic Suite is uncertain. The age must be younger than that of the Exocaldera Sequence of the Piskahegan Group, which is constrained by a U–Pb radiometric age of 363.4 ± 1.8 Ma for the Bailey Rock Rhyolite. K–Ar and Rb–Sr studies indicate a Late Mississippian age of 340 Ma to 330 Ma. However, a K–Ar date of 361 ± 9 Ma from biotite hornfels in sedimentary breccia underlain by Granite III appears to confirm a Late Devonian to Early Mississippian age.

Mineralization

Mineralization at the Mount Pleasant deposit is hosted mainly by Granite I (W–Mo–Bi) and Granite II (Sn–In) of the Mount Pleasant Granitic Suite. Isolated occurrences of tin mineralization occur within Granite III.

In both the Fire Tower Zone and North Zone (Fig. 26, 27), breccias and associated intrusive rocks form irregular, roughly vertical, pipe-like complexes that were centres of subvolcanic intrusive and related hydrothermal activity. The breccias range from groundmass-supported

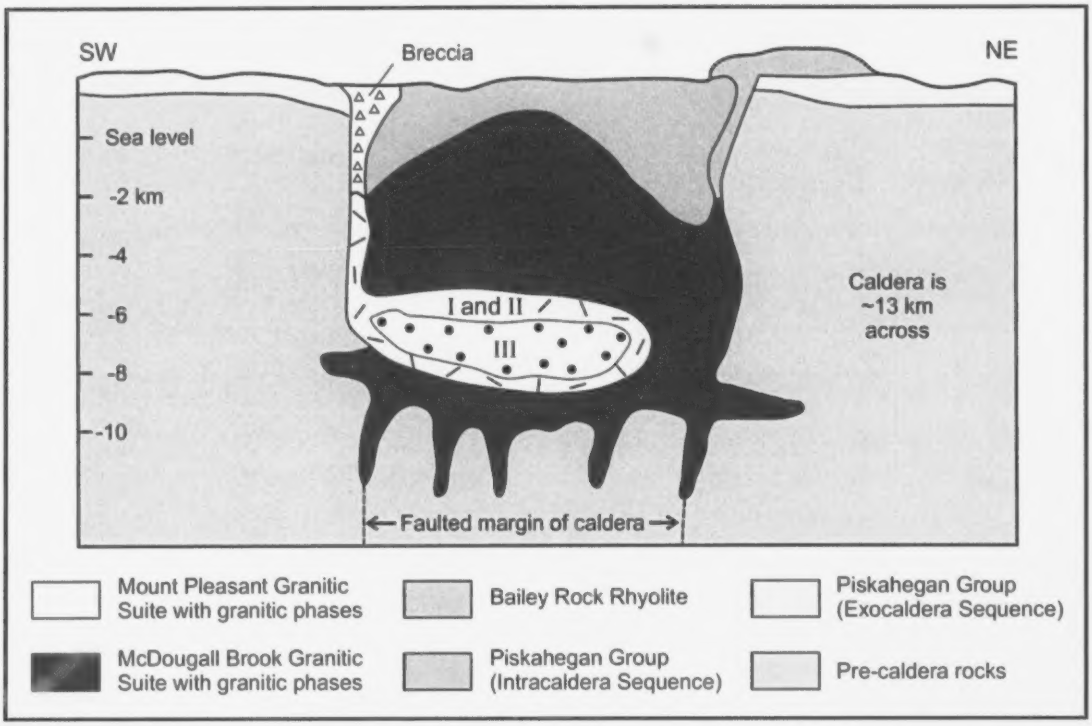

SW
Breccia
NE
Sea level
-2 km
-4
-6
-8
-10
I and II
III
Caldera is ~13 km across
Faulted margin of caldera
Mount Pleasant Granitic Suite with granitic phases
Bailey Rock Rhyolite
Piskahegan Group (Exocaldera Sequence)
McDougall Brook Granitic Suite with granitic phases
Piskahegan Group (Intracaldera Sequence)
Pre-caldera rocks

Figure 25. Hypothetical model for the generation of the McDougall Brook and Mount Pleasant granitic suites in the Mount Pleasant Caldera Complex (after McCutcheon et al. 1997 and Yang et al. 2003). Crystal fractionation took place at depth as the magma cooled and solidified toward the centre of the magma chamber, resulting in compositional zoning of the McDougall Brook Granitic Suite into MBG1, MBG2, and MBG3. Subsequent fluid fractionation concentrated fluorine and water in the magma chamber, which prolonged its crystallization history and produced extreme enrichment of incompatible elements such as Rb, Li, Cs, Nb, Sn, and W. Pulses of these enriched magmas (i.e., Granites I and II of the Mount Pleasant Granitic Suite) were then injected into higher levels of the volcanic pile along the western margin of the caldera complex, leaving Granite III relatively depleted in metals.

with rounded fragments to clast-supported with mainly angular fragments. Both the fragments and groundmass material have been altered extensively, and in many places the fragment protoliths are difficult to identify.

Tungsten–Molybdenum–Bismuth Mineralization

The tungsten–molybdenum–bismuth mineralization was generated by Granite I and is hosted mainly by Granite I and related breccia and, to a lesser extent, by associated country rocks. The mineralization occurs in fractures, quartz veinlets, and disseminations in the breccia matrix. Wolframite and molybdenite are the principal ore minerals, accompanied by minor bismuth and bismuthinite. Quartz, topaz, fluorite, arsenopyrite, and loellingite are the primary gangue minerals.

Several types of alteration are associated with the tungsten–molybdenum–bismuth mineralization. Intense and pervasive silicic or greisen-type alteration occurs within and above the high-grade tungsten–molybdenum orebodies and is characterized by the complete

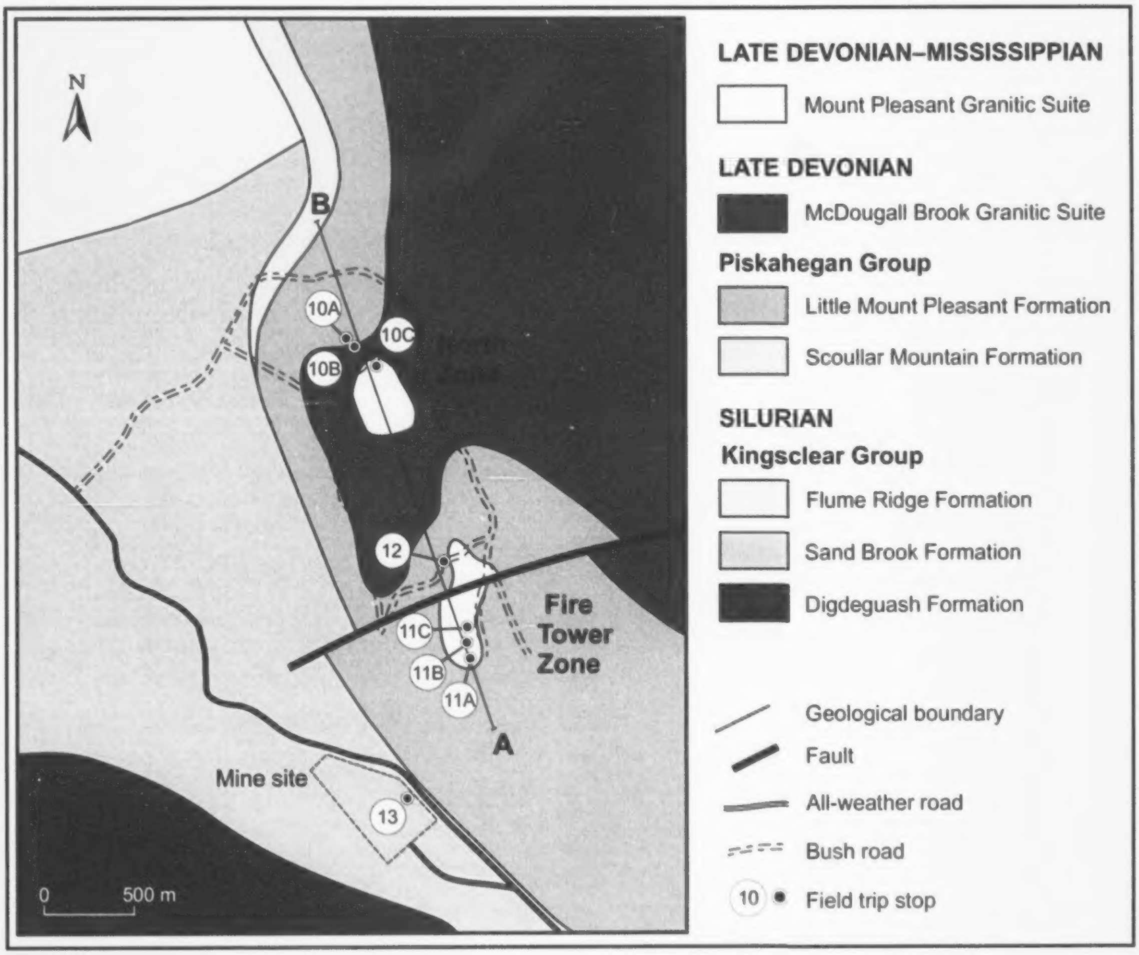

N
B
10A
10C
10B
North Zone
12
Fire Tower Zone
11C
11B
11A
A
Mine site
13
0 500 m
LATE DEVONIAN–MISSISSIPPIAN
Mount Pleasant Granitic Suite
LATE DEVONIAN
McDougall Brook Granitic Suite
Piskahegan Group
Little Mount Pleasant Formation
Scoullar Mountain Formation
SILURIAN
Kingsclear Group
Flume Ridge Formation
Sand Brook Formation
Digdeguash Formation
Geological boundary
Fault
All-weather road
Bush road
10 Field trip stop

Figure 26. Simplified geology map of the Mount Pleasant deposit, showing the location of field trip stops and cross-section A–B, below (after McCutcheon et al. 1997). See Figure 23 for map location.

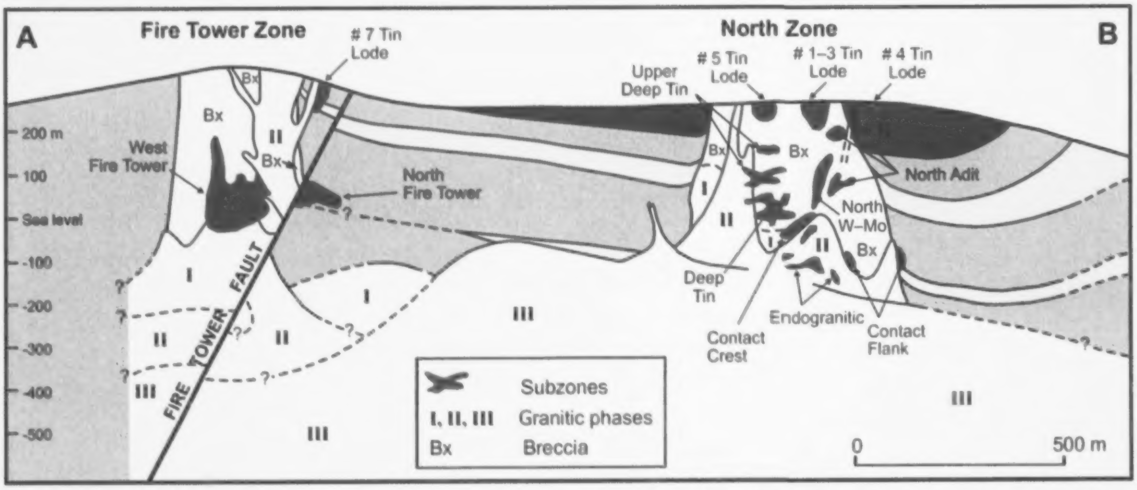
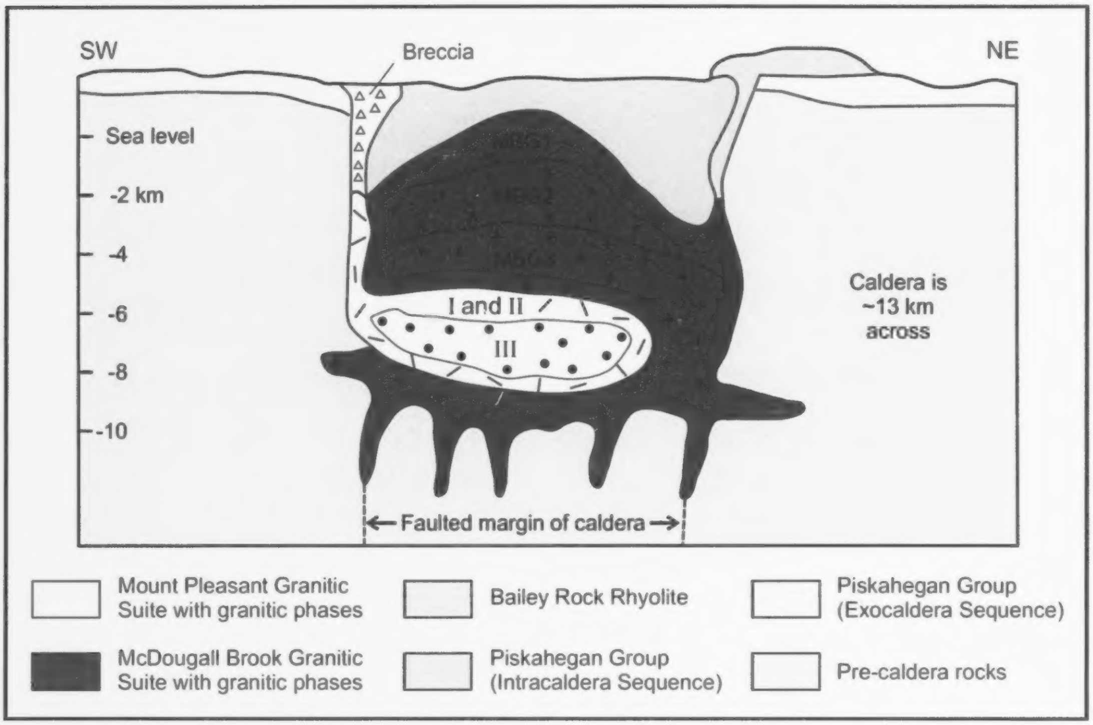

A
Fire Tower Zone
# 7 Tin Lode
North Zone
B
Upper Deep Tin
# 5 Tin Lode
# 1–3 Tin Lode
# 4 Tin Lode
200 m
100
Sea level
-100
-200
-300
-400
-500
West Fire Tower
Bx
II
North Fire Tower
North Adit
North W–Mo
Deep Tin
Endogranitic
Contact Crest
Contact Flank
I
II
III
FIRE TOWER FAULT
Subzones
I, II, III Granitic phases
Bx Breccia
0 500 m

Figure 27. Cross-section A–B through the Fire Tower Zone and North Zone, showing ore subzones (after McCutcheon et al. 1997). See Figure 26 for colour legend and section line. View looking west.


SW
Breccia
NE
Sea level
-2 km
-4
-6
-8
-10
MBG1
MBG2
MBG3
I and II
III
Caldera is ~13 km across
Faulted margin of caldera
Mount Pleasant Granitic Suite with granitic phases
Bailey Rock Rhyolite
Piskahegan Group (Exocaldera Sequence)
McDougall Brook Granitic Suite with granitic phases
Piskahegan Group (Intracaldera Sequence)
Pre-caldera rocks

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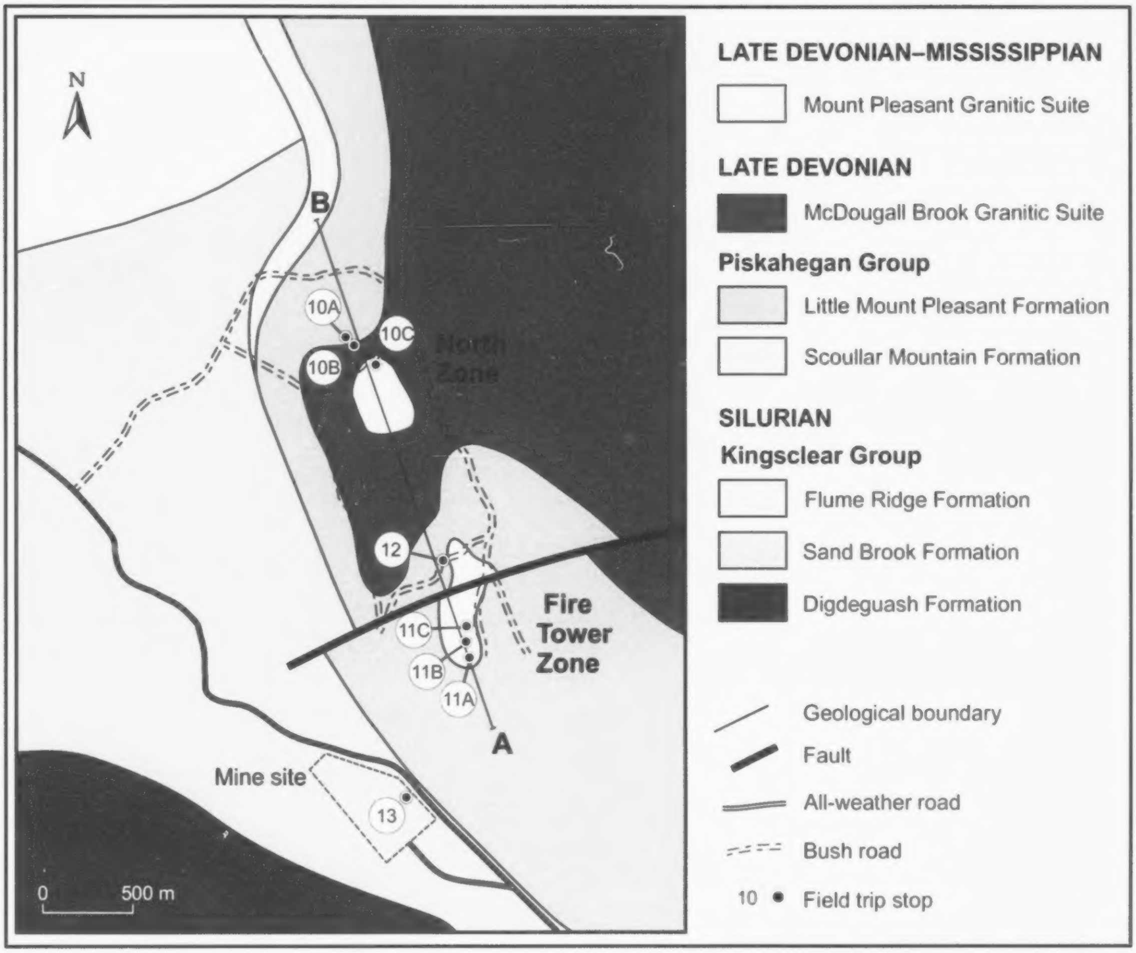
N
B
10A
10B
10C
North Zone
12
11C
11B
11A
Fire Tower Zone
A
Mine site
13
0 500 m
LATE DEVONIAN–MISSISSIPPIAN
Mount Pleasant Granitic Suite
LATE DEVONIAN
McDougall Brook Granitic Suite
Piskahegan Group
Little Mount Pleasant Formation
Scoullar Mountain Formation
SILURIAN
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Flume Ridge Formation
Sand Brook Formation
Digdeguash Formation
Geological boundary
Fault
All-weather road
Bush road
10 ● Field trip stop

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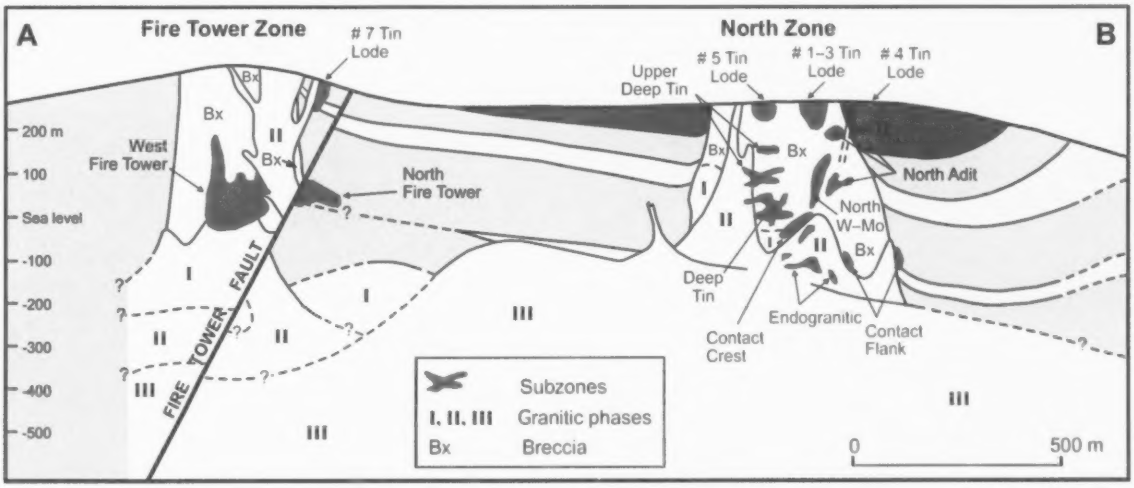
A
Fire Tower Zone
# 7 Tin Lode
North Zone
B
Upper Deep Tin
# 5 Tin Lode
# 1–3 Tin Lode
# 4 Tin Lode
200 m
100
Sea level
-100
-200
-300
-400
-500
Bx
West Fire Tower
II
North Fire Tower
North Adit
North W–Mo
Deep Tin
Endogranitic
Contact Crest
Contact Flank
I
III
?
FIRE TOWER FAULT
Subzones
I, II, III Granitic phases
Bx Breccia
0 500 m

Figure 27. Cross-section A–B through the Fire Tower Zone and North Zone, showing ore subzones (after McCutcheon et al. 1997). See Figure 26 for colour legend and section line. View looking west.

or nearly complete replacement of host rocks by quartz, topaz, sericite, and fluorite. The alteration grades outward to a less intense silicic alteration that is limited mainly to narrow selvages on mineralized fractures and quartz veinlets. Quartz, biotite, chlorite, and minor topaz are the principal minerals of this alteration stage, which extends laterally up to 100 m beyond the high-grade tungsten–molybdenum orebodies. Propylitic alteration consisting of chlorite and sericite surrounds the silicic alteration and extends for more than 1000 m before grading into relatively unaltered rock (Pouliot et al. 1978; Kooiman et al. 1986).

Tungsten–molybdenum–bismuth mineralization occurs mainly in the Fire Tower Zone, but one subzone of tungsten–molybdenum has also been intersected in the North Zone (Fig. 26).

Tin–Indium Mineralization

Tin–indium mineralization was generated by Granite II and occurs as sulphide-rich polymetallic veins and replacement bodies that are superimposed on the tungsten–molybdenum–bismuth mineralization (generated by Granite I). Sphalerite, chalcopyrite, arsenopyrite, and cassiterite are the dominant ore minerals. They are associated with chlorite, fluorite, topaz, and a complex assemblage of sulphides and sulpharsenides that include loellingite, galena, pyrite, marcasite, molybdenite, tennantite, bornite, bismuthinite, wittichenite, and roquesite.

Most of the potentially economic tin orebodies occur in the North Zone between the depths of 200 m and 400 m below surface. These include the Upper Deep Tin, Deep Tin, Contact Crest, Contact Flank, and Endogranitic subzones (Fig. 27). The *Deep Tin Subzone* is a relatively large, irregular orebody that consists of fracture-controlled and disseminated cassiterite hosted within silicified and chloritized breccia and Granite I. Other minerals associated with cassiterite include arsenopyrite, sphalerite, chalcopyrite, and galena. The *Contact Crest* and *Contact Flank* subzones occur mainly in breccia or other associated host rocks at the upper contact or along the sides of Granite II. The *Endogranitic Subzone*, on the other hand, occurs mainly *within* Granite II. In these subzones, cassiterite appears as finely disseminated grains and as fine- to medium-sized grains in veins or veinlets and along fractures. Associated minerals include arsenopyrite, sphalerite, chalcopyrite, pyrite, and pyrrhotite. Chlorite, fluorite, and topaz are the main alteration minerals. Cross-cutting relationships indicate that several stages of alteration and mineralization may be present.

Tin–indium mineralization occurs primarily in the North Zone but also has been intersected in the Fire Tower Zone, where indium grades range from 50 g/t to 300 g/t In. The indium occurs mainly as a solid solution in sphalerite and, to a lesser extent, in chalcopyrite and stannite.

RESOURCE ESTIMATES

The estimated resource in the Fire Tower Zone before mining in the 1980s totalled 22.5 Mt grading 0.21% W, 0.10% Mo, and 0.08% Bi (Parrish and Tully 1978). About 11 Mt of similar-grade material were estimated to be in the North Zone. Included in this resource were higher grade orebodies in the Fire Tower Zone containing a total of 9.4 Mt grading 0.39% WO_3 and 0.20% MoS_2 (Kooiman et al. 1986). When the Mount Pleasant deposit was mined (1983–85), the operation produced about 2000 t of concentrate grading 70% WO_3 from about I Mt of ore.

The most recent resource estimates by Adex Mining Inc. for the Fire Tower Zone and North Zone are shown below (Tables 5, 6). These figures are from Dunbar et al. (2008) and Dunbar and de l'Etoile (2009), respectively, and are compliant with National Instrument 43-101, *Standards of Disclosure for Mineral Projects*.

Table 5. Mineral resource estimate for the Fire Tower Zone, Mount Pleasant deposit.

Subzones	Tonnes	WO_3 %	MoS_2 %	As %	Bi %
Indicated	See Figure 27 for location of subzones.				
West Fire Tower	9,148,900	0.32	0.21	0.29	0.04
North Fire Tower	4,340,100	0.35	0.20	1.15	0.09
Total Indicated	**13,489,000**	**0.33**	**0.21**	**0.57**	**0.06**
Inferred					
West Fire Tower	831,000	0.26	0.20	0.21	0.04
North Fire Tower	10,700	0.26	0.17	0.26	0.05
Total Inferred	**841,700**	**0.26**	**0.20**	**0.21**	**0.04**

Note: Reported at a cutoff of 0.3% WO_3 equivalent grade. WO_3 equivalent % = WO_3 % + 1.5 x MoS_2 %.

Table 6. Mineral resource estimate for the North Zone, Mount Pleasant deposit.

Subzones	Tonnes	Sn %	In g/t	In g/t (capped)	Zn %	As %	WO_3 %	MoS_2 %	Cu %	Bi %
Indicated	See Figure 27 for location of subzones.									
Deep Tin	5,006,000	0.39	101.0	95.2	0.86	1.25	0.08	0.06	0.14	0.08
Endogranitic	4,336,000	0.55	21.8	20.3	0.28	0.85	0.12	0.06	0.10	0.09
Upper Deep Tin	838,000	0.22	102.8	94.9	1.36	0.76	0.08	0.06	0.07	0.05
# 4 Tin Lode	702,000	0.25	74.1	74.1	1.00	0.19	0.01	0.01	0.09	0.00
Total Indicated	**10,882,000**	**0.43**	**67.8**	**64.0**	**0.67**	**0.98**	**0.09**	**0.06**	**0.11**	**0.08**
Inferred										
# 1-3 Tin Lode	2,345,000	0.18	76.8	73.5	1.08	0.28	0.02	0.03	0.09	0.01
# 5 Tin Lode	1,267,000	0.15	115.4	111.3	1.50	0.70	0.07	0.04	0.08	0.03
North Adit	3,076,000	0.27	62.1	62.1	0.83	1.16	0.09	0.06	0.09	0.07
North W–Mo	915,000	0.26	54.3	49.8	0.58	1.14	0.25	0.12	0.12	0.10
Total Inferred	**7,603,000**	**0.22**	**74.6**	**72.3**	**.99**	**0.80**	**0.08**	**0.05**	**0.09**	**0.05**

Note: Reported at a cutoff of 0.25% Sn equivalent (SnEQ). SnEQ % = Sn % + 41.67 In %.

STOP DESCRIPTIONS

Stop 1: Sandstone and Conglomerate (Shin Formation)

From Fredericton, head south on Regent Street and proceed toward New Maryland. Follow Highway 101 to Central Blissville and turn right onto Highway 785 (approximately 42 km from Fredericton). After 200 m, bear right after the crossroads onto the road to Mount Pleasant (Route 785). Stop 1 is 11.7 km along the road, just after the bridge that crosses Shin Creek.

Gently north-dipping redbeds in the roadcut (Fig. 23) are typical of the lower part of the Shin Formation of the Mabou Group (Fig. 28). Poorly sorted, coarse-grained sandstone beds (up to 0.5 m in thickness) have sharp basal contacts and are normally graded from pebbly granule conglomerate to fine-grained sandstone. The pebbles are subangular to well rounded and mostly nonvolcanic: that is, they are not derived from the Piskahegan Group.

The interbedded reddish brown mudstone locally contains calcareous nodules (calcrete), which are abundant at one locality downstream from the bridge over Shin Creek. The Shin Formation is post-middle Visean (post-Middle Mississippian) and unconformably overlies the Piskahegan Group.

Stop 2: Pumice Breccia (Kleef Formation)

From Stop 1, proceed for 200 m on Route 785 and turn left onto the bush road. Stop 2 is 500 m down the road.

The reddish brown subcrop on the right side of the road (Fig. 23) is representative of the upper member of the Kleef Formation (Fig. 29), part of the Late Caldera-Fill Sequence (Piskahegan Group). Pseudomorphed pumice fragments, which are darker than the matrix, are up to 3 cm long and make up 10% to 15% of the individual blocks. Many preserve a remnant tubular structure that is manifested as lineation on the flattened surfaces of the fragments.

Some calcitized fragments (fossil pumice) are unflattened and consequently better preserve this original structure. The calcitized fragments demonstrate that the eutaxitic foliation in the rock resulted from burial compaction rather than welding. This tuff also contains 5% to 10% lithic fragments, mostly felsic volcanic rocks, which rarely exceed 1 cm in size. Quartz and feldspar phenocrysts (<1.0 mm) constitute less than 5% of the rock.

Stop 3: Basalt (Kleef Formation)

From Stop 2, drive east along the bush road for 700 m. After the sharp left turn in the road, proceed for another 500 m to Stop 3. Park at the junction in the road and proceed on foot along the left (northwest) branch for about 300 m to the power line.

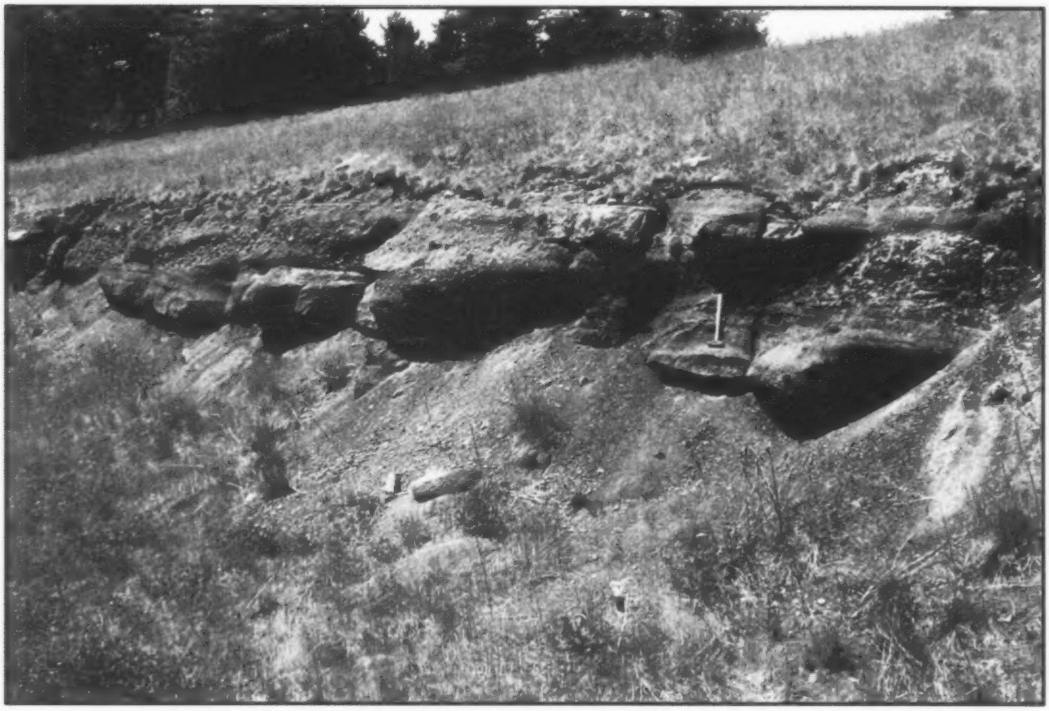

Figure 28. Gently north-dipping redbeds, typical of the lower part of the Shin Formation (Mabou Group), in roadside exposures at Stop 1. Hammer for scale.

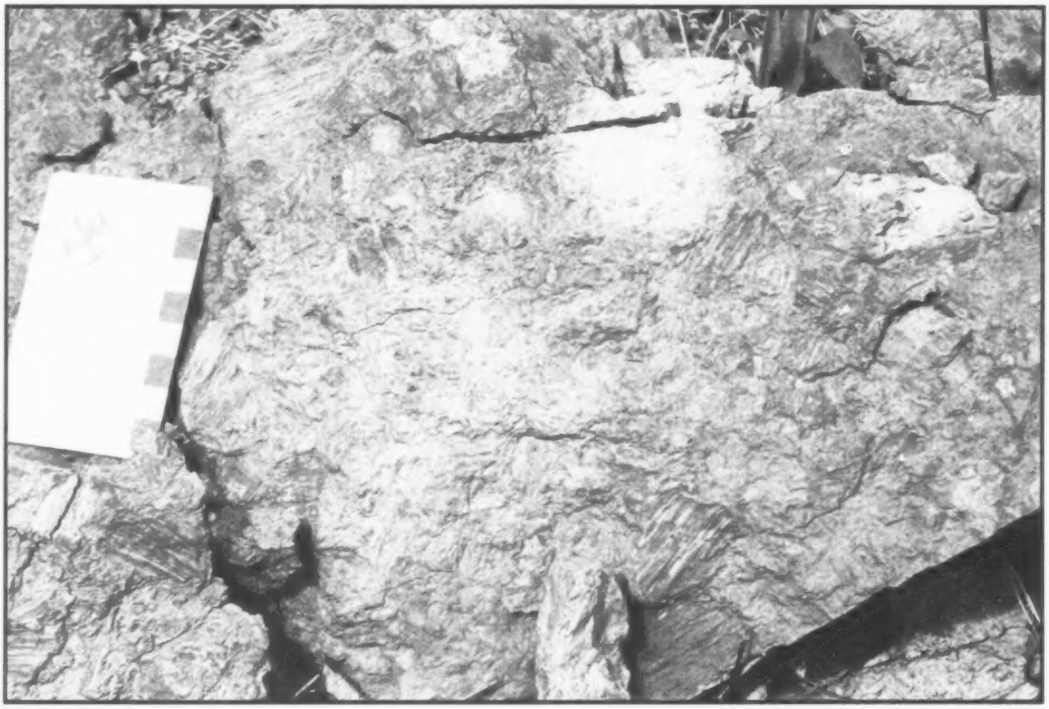

Figure 29. Reddish brown pumice breccia from upper member of the Kleef Formation (Piskahegan Group) in a subcrop at Stop 2.

Flat outcrops and subcrops of light to olive grey basalt occur beside the trail (Fig. 23). This basalt constitutes the middle member of the Kleef Formation and is characterized by plagioclase phenocrysts up to 2 cm long and locally glomerocrysts up to 4 cm across (Fig. 30). The basalt also contains scattered dark reddish brown amygdules up to 1 cm long, which are filled or rimmed by reddish brown hematite and are commonly cored by chalcedony. The Kleef Basalt is underlain by pebble to cobble conglomerate (lower member) that can be seen about 500 m to the northeast, where the power line crosses Shin Creek. This conglomerate contains abundant clasts of Bailey Rock Rhyolite, part of the Exocaldera Sequence. About 10 km to the west, Kleef conglomerate contains clasts of Seelys crystal tuff, part of the Intracaldera Sequence. Thus, the age relationship of these two sequences with the Late Caldera-Fill Sequence is established.

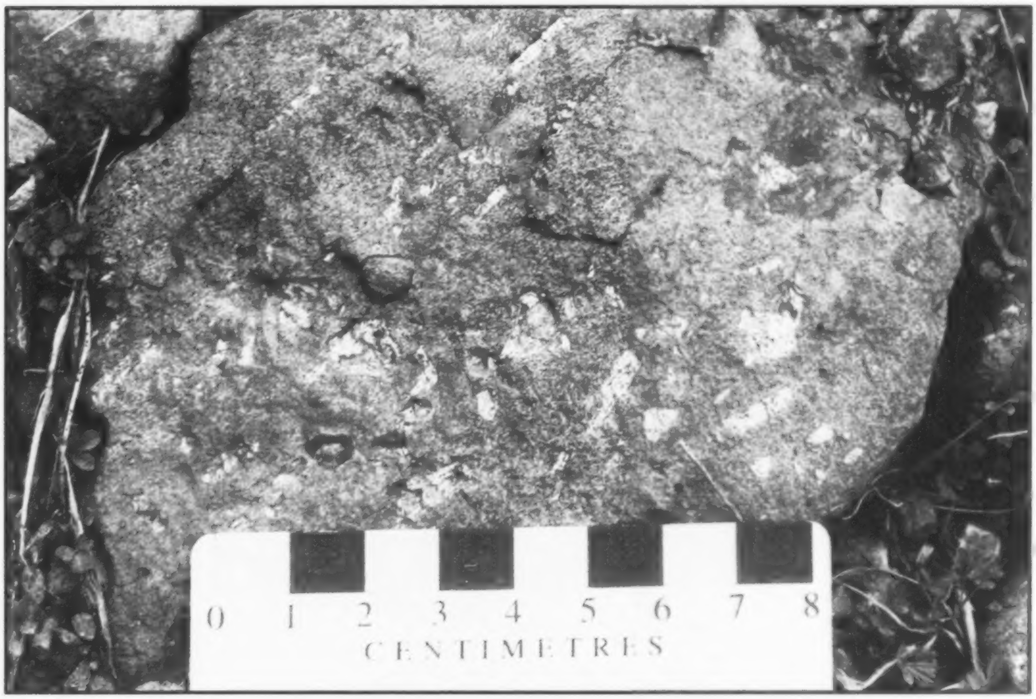

Figure 30. Basalt of the Kleef Formation in flat outcrops along the trail at Stop 3.

Stop 4: Flow-Layered Rhyolite (Big Scott Formation)

From Stop 3, drive back to Route 785. Turn left, head south on Route 785, and proceed for 1.5 km to the quarry on the left side of the road.

Greyish red, feldspar-phyric, flow-layered rhyolite on the east side of the road marks the base of the Late Caldera-Fill Sequence (Fig. 23, 24). The contact with the underlying McDougall Brook Granitic Suite at the southern end of the outcrop is concealed, but the flow layering near the base dips gently northward (Fig. 31a). The rhyolite contains abundant spherulites and examples of flow folds. Feldspar phenocrysts, mostly <1 mm, constitute 10% to 15% of the rock (Fig. 31b). Brecciated silica veins cut the outcrop in several places. A subcrop of fine-grained porphyritic granite can be seen about 50 m south of the rhyolite.

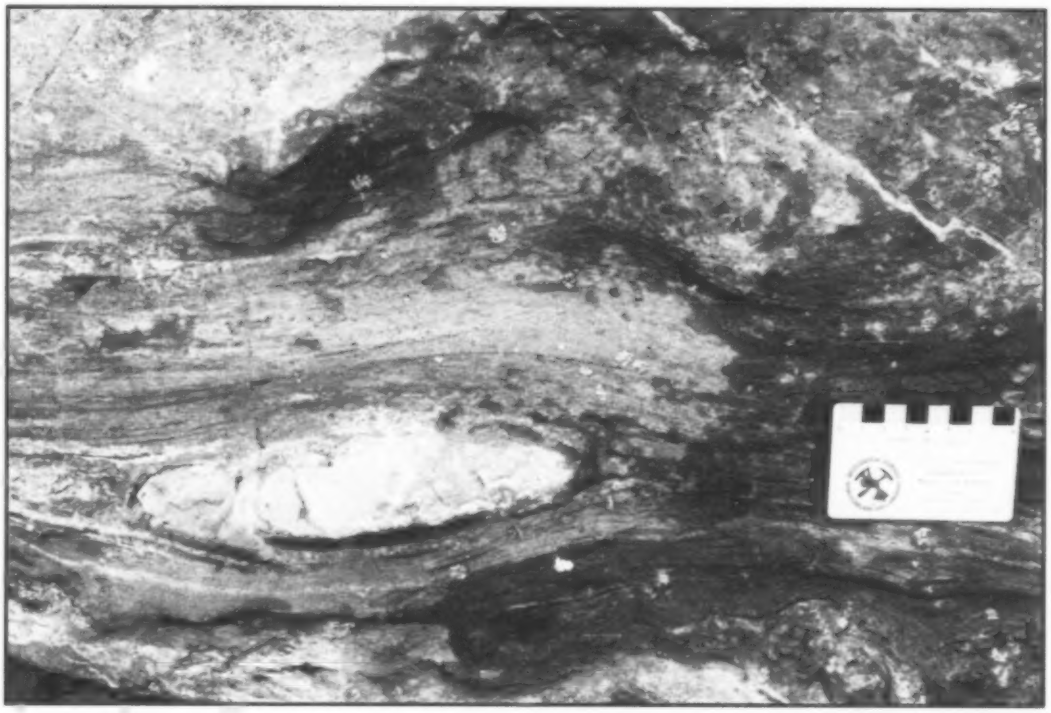

Figure 31a. Flow layering and sparse phenocrysts in rhyolite of the Big Scott Formation at Stop 4.

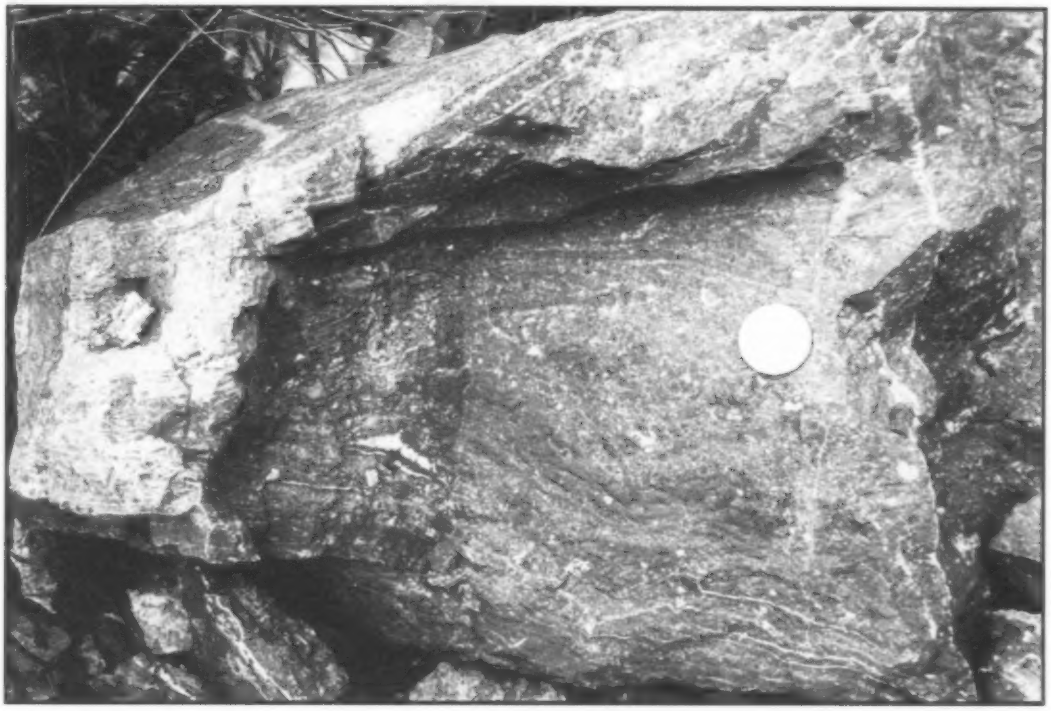

Figure 31b. Feldspar phenocrysts in rhyolite of the Big Scott Formation at Stop 4. Coin diameter is 2.7 cm.

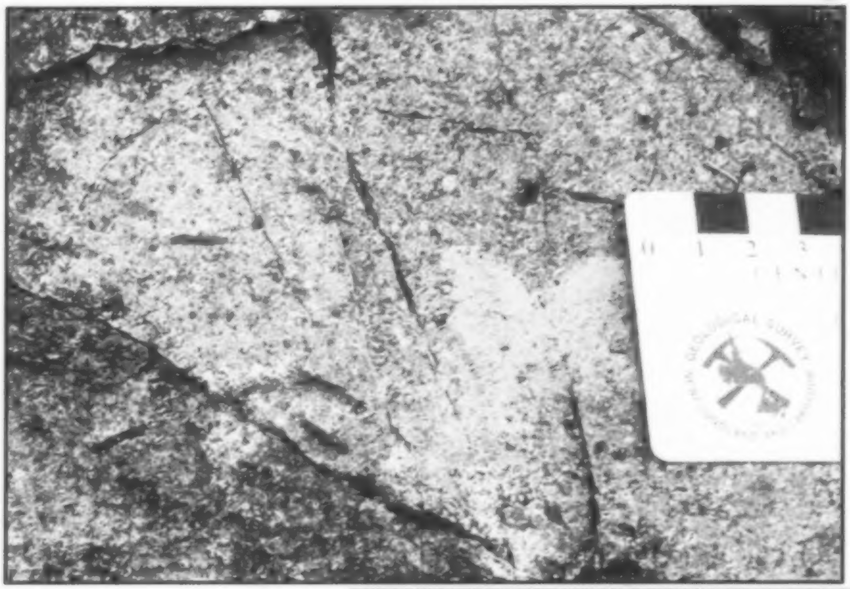

Figure 32a. Porphyritic monzogranite, defined as the main phase (MBG2: see Fig. 25) of the McDougall Brook Granitic Suite.

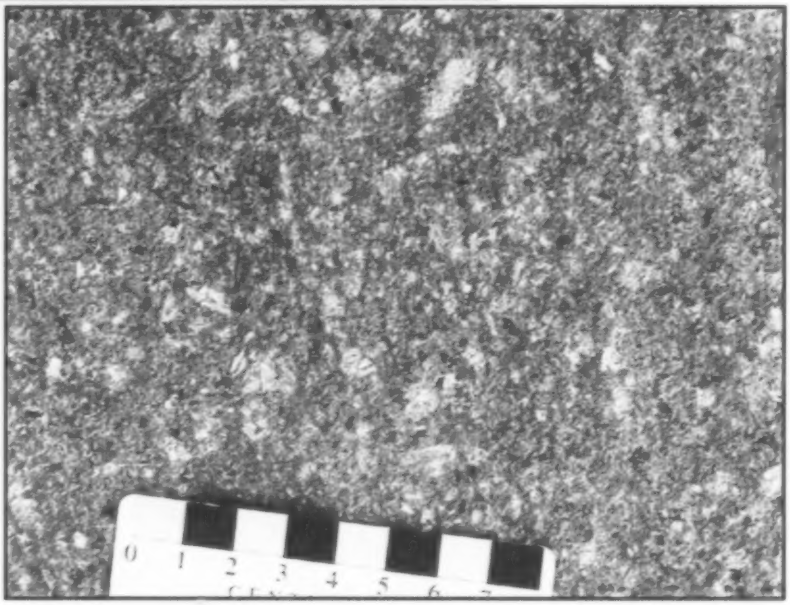

Figure 32b. Crystal tuff in the upper part of the Seelys Formation.

Stop 5: McDougall Brook Granitic Suite–Seelys Formation Contact

After returning to the vehicles at Stop 4, continue south on Route 785. Stop 5 is 1.5 km down the road from Stop 4.

This roadcut (Fig. 23) shows the intrusive relationship of the McDougall Brook Granitic Suite (Fig. 32a) to the crystal tuff typical of the upper part of the Seelys Formation (Fig. 32b). Greyish red crystal tuff in the southern part of the outcrop contains abundant (25–35%) quartz and feldspar phenocrysts and phenoclasts, most of which are <2 mm in size. Locally, this tuff contains greenish grey metasedimentary clasts (generally <1.5 cm); some clasts have reaction rims. The fine-grained, porphyritic monzogranite in the northern part of the outcrop has a mottled appearance and contains abundant (15–35%) feldspar phenocrysts (up to 10 mm but mostly <3 mm) and lesser amounts (5–15%) of ferromagnesian minerals (mostly <1 mm) in a microcrystalline groundmass. The grain size of the groundmass decreases from phaneritic to aphanitic in proximity to the contact with the tuff. Minor quartz phenocrysts occur near the contact.

Stop 6: Crystal Tuff (Seelys Formation)

Return to the vehicles and continue south on Route 785. On the right hand side of the road at 2.3 km down the road is an outcrop of crystal tuff of the Seelys Formation. At 3.1 km from this outcrop is a junction with bush road #61 on the left. Turn left onto this road and proceed for 300 m to the power line and a junction with another bush road on the right; turn right and head south. Stop 6 is 2.0 km from the power line. Park at the ridge crest and walk about 200 m southwest along the sparsely treed crest, through the saddle, to the end of the ridge. On a clear day, Mount Pleasant is visible to the southwest from this location.

The outcrops on the hillside (Fig. 23) constitute a reference section for the lower part of the Seelys Formation (Fig. 33a, 33b). The rocks exhibit very little lithologic variation over the 29 m of section from the apparent base to the apparent top of the section. They comprise greyish red to pale reddish brown crystal tuffs, containing highly flattened pumice pseudomorphs (Fig. 33a). Pink feldspar is slightly more abundant than clear quartz; combined, these crystals (0.5–3.5 mm) constitute 15% to 25% of the rock. The largest crystals appear inside the pumice pseudomorphs that make up 10% to 20% of the rock.

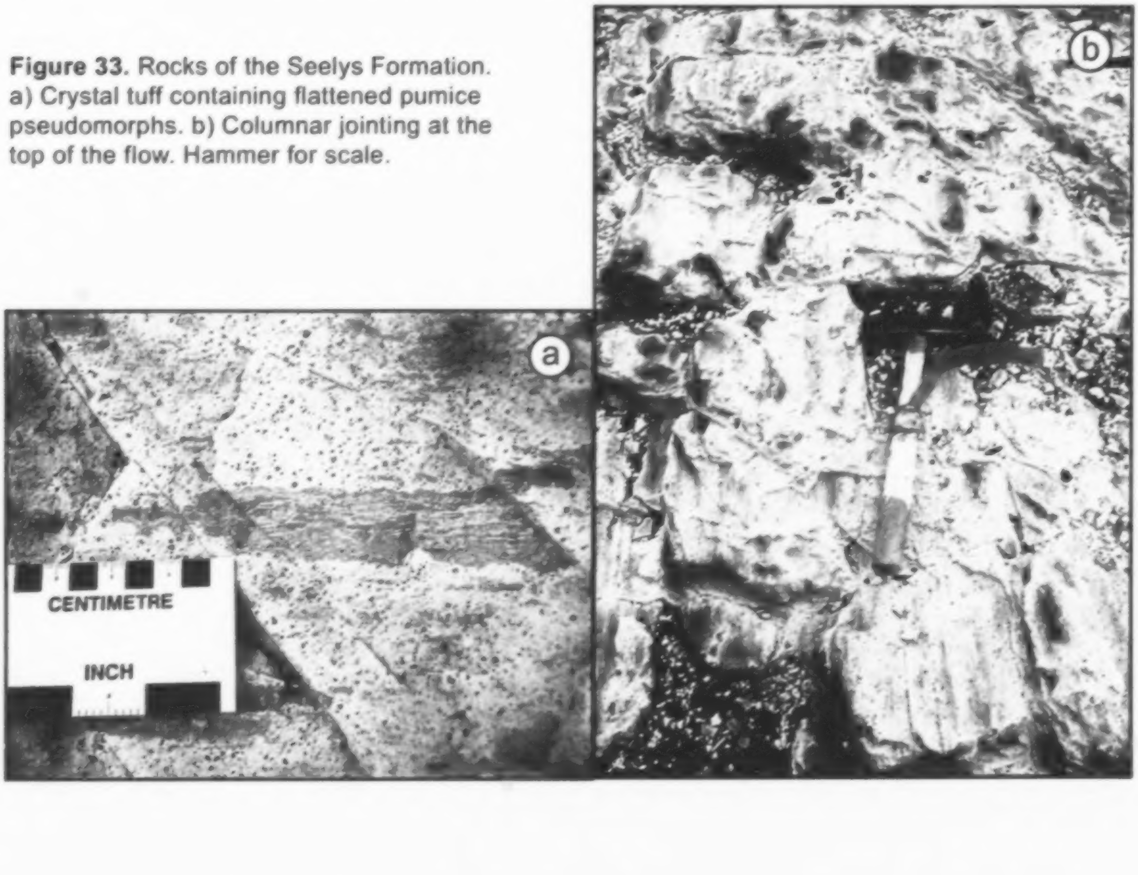

Figure 33. Rocks of the Seelys Formation. a) Crystal tuff containing flattened pumice pseudomorphs. b) Columnar jointing at the top of the flow. Hammer for scale.

Poorly developed columnar jointing (Fig. 33b) is visible on the vertical face of each plateau and lies perpendicular to a well-developed, northerly dipping (about 25°) eutaxitic foliation. At the summit of the hill, flattened and stretched pumice pseudomorphs can be seen on the tops of the columnar joints. A subcrop of Little Mount Pleasant Formation occurs less than 100 m southeast of the base of the hill. The northerly dipping eutaxitic foliation and higher topographic elevation indicate that the Seelys Formation overlies the Little Mount Pleasant Formation.

Stop 7: McDougall Brook Granitic Suite–Little Mount Pleasant Formation Contact

Return to the vehicles and continue south. About 100 m down the road is a junction with another bush road on the left (east); turn around and drive back to Route 785. Turn left onto Route 785 and proceed for 3.8 km and park just past Piskahegan Stream near the junction with the bush road on the right.

At this location (Fig. 23), flat-lying outcrops of crystal tuff of the Little Mount Pleasant Formation (Fig. 26) contain about twice as much feldspar as quartz. Collectively, these crystals (0.5–3.0 mm) comprise 30% to 40% of the rock. Where unaltered, the tuff is generally greyish red (Fig. 34a), but here, near the contact with the McDougall Brook Granitic Suite, it is greenish grey due to effects of hydrothermal alteration. Outcrops of dark greyish red feldspar porphyry that constitute the border phase of the McDougall Brook suite (MBG1) occur 150 m to the northeast (Fig. 34b). The porphyry contains two populations of subhedral to euhedral feldspar phenocrysts (1–12 mm) with plagioclase generally slightly more abundant than K-feldspar. Combined, these phenocrysts make up 20% to 35% of the rock. The porphyry also contains minor (<2%) clear quartz phenocrysts (1–4 mm). Note the aphanitic nature of the groundmass.

Stop 8: Hydrothermal Breccia in McDougall Brook Granitic Suite

From Stop 7, continue south on Route 785 for 1.9 km to the junction with the bush road on the left (east) just past the blind knoll; turn left. Stop 8 is 300 m down the bush road, on the left side of the road.

Heterolithic, silicified breccia exposed on the north side of the road (Fig. 23) contains fragments of the Little Mount Pleasant Formation and feldspar porphyry (Fig. 35). Some fragments show evidence of rounding, but most are angular. The breccia is part of a small enclave within the McDougall Brook Granitic Suite and is interpreted as a hydrothermal breccia that is part of the Intravolcanic Sequence

McDougall Brook granitic rocks are exposed about 100 m farther east on the north side of the road as a reddish grey, fine-grained porphyritic monzogranite (MBG2). About 150 m farther along, on the south side of the road, they are greenish grey and contain inclusions of older granitoid rocks. An additional 150 m down the road, on the north side, the McDougall Brook granitic rocks are greyish red and transitional between the fine-grained porphyritic monzogranite (main phase: MBG2) and the feldspar porphyry (border phase: MBG1).

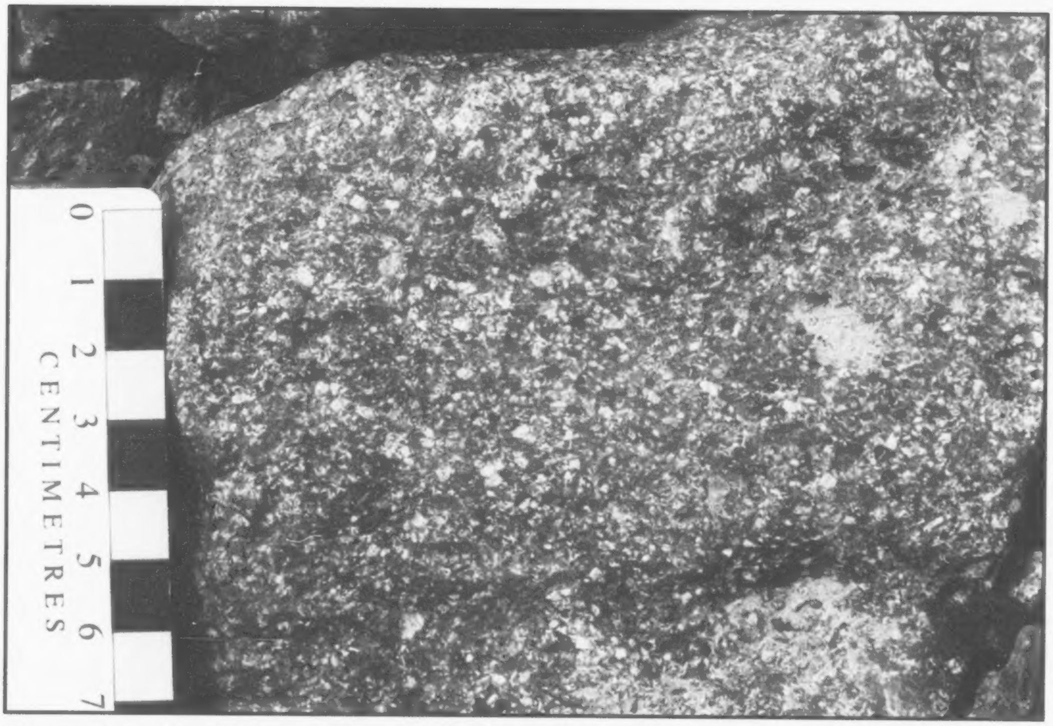
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Figure 34a. Crystal tuff of the Little Mount Pleasant Formation at Stop 7, showing predominance of feldspar phenocrysts over quartz phenocrysts.

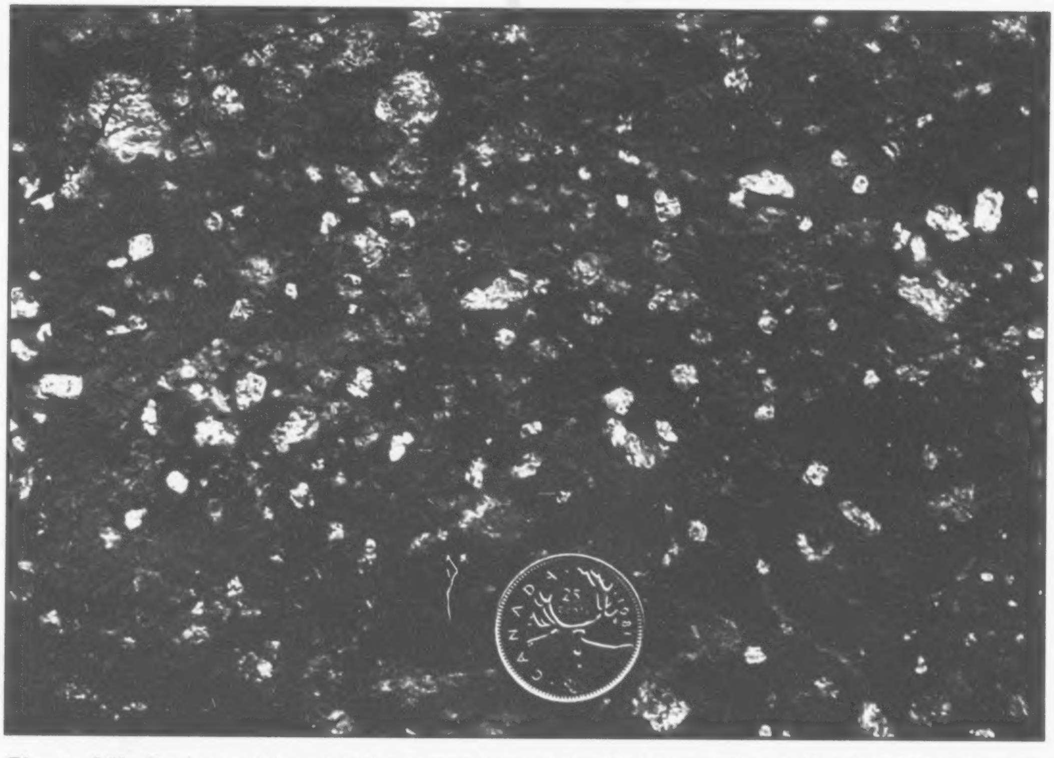
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Figure 34b. Dark greyish red feldspar porphyry of the McDougall Brook Granitic Suite (border phase: MBG1). Coin diameter is 2.4 cm.

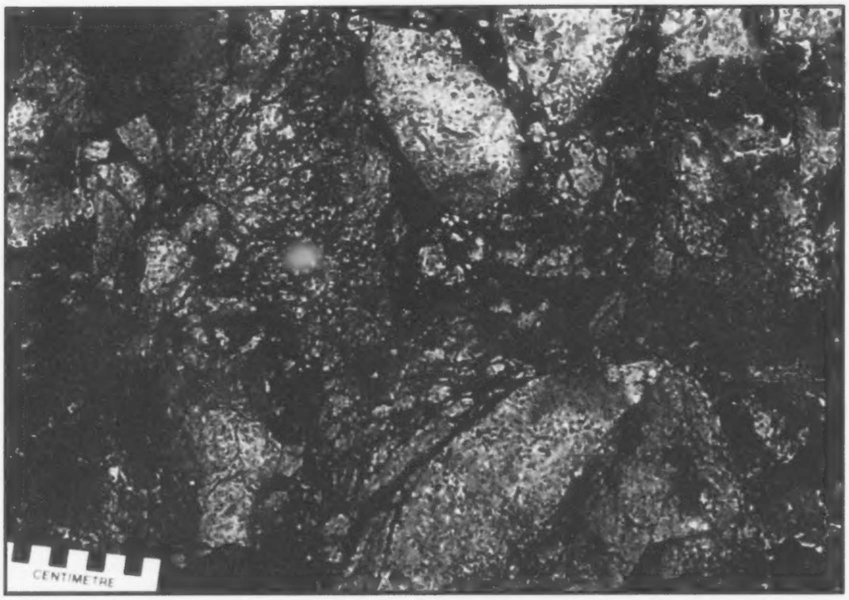

Figure 35. Heterolithic, silicified breccia of the McDougall Brook Granitic Suite at Stop 8, showing rounded and angular fragments.

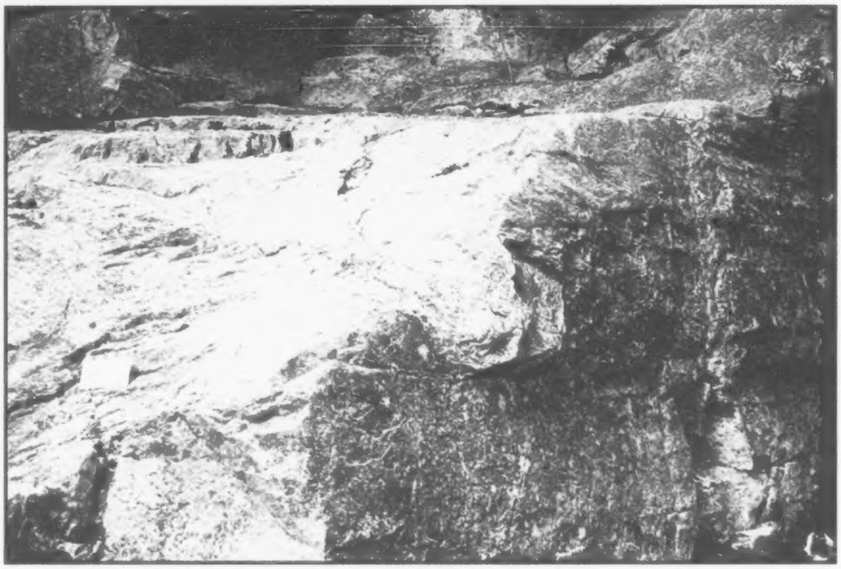

Figure 36. Quartz–feldspar crystal tuff of the Little Mount Pleasant Formation at Stop 9 along Hatch Brook, showing moderately well-developed eutaxitic foliation. Scale is in centimetres.

Stop 9: Quartz–Feldspar Crystal Tuff (Little Mount Pleasant Formation)

Walk back to the vehicles at Stop 8 and continue east on the bush road. A bridge crosses Piskahegan Stream at 500 m from Stop 8. About 300 m after the bridge is a junction with the bush road on the right; turn around and drive back to Route 785. Once reaching Route 785, turn left (south) and proceed for 7 km to the junction with the road to the Mount Pleasant mine site on the right; turn right. Proceed for 2.1 km and stop alongside the road.

Quartz–feldspar crystal tuff with moderately well-developed eutaxitic foliation is exposed in the streambed of Hatch Brook on the east side of the road (Fig. 23, 36). The foliation is outlined by dark green fiamme or extremely flattened pumice pseudomorphs. The outcrop here is one of the few of this formation to display eutaxitic foliation.

Stop 10: Mount Pleasant North Zone

Return to the vehicles and continue toward the mine site. The turnoff to the site is on the left at 1.3 km from Stop 9. Park at the mine office. Note: Before continuing to the next stop, you need to obtain permission from the mine owner and get the key to the north gate. Turn around and return to the main road. Turn left and head northwest for 2.8 km. Turn off to the north gate on the right; open gate and proceed through, making sure that occupants of the last vehicle close and lock the gate behind them. Continue along for 1 km to the junction with the road on the right; bear right. At 0.5 km, bear left up the hill at the Y-intersection and proceed another 300 m to the old northwesterly trending trench. Walk 175 m to the northwest along the old trenched area.

10A: Massive Porphyritic Rhyolite (Little Mount Pleasant Formation). The outcrop at this location (Fig. 26) is partly chloritized but can be recognized by the quartz and feldspar phenocrysts that typically are 2 mm to 3 mm in size (Fig. 37a). Fractures and quartz veinlets in the porphyritic rhyolite locally contain sulphide minerals.

Walk 15 m back toward the road.

10B: Feldspar Porphyry (McDougall Brook Granitic Suite). The feldspar porphyry (MBG1) here is distinguished from the porphyritic monzonite (MBG2) in having feldspar phenocrysts up to 1 cm in size and generally less than 5% quartz phenocrysts (Fig. 37b). The contact between the feldspar porphyry and porphyritic monzonite is marked by a local change in slope.

Walk back past the vehicles to the newer trenched area on the south side of the road.

10C: Mineralized North Zone Breccia. On the south side of the road (Fig. 26), fine-grained tin minerals (cassiterite and stannite) and base metal sulphides occur locally in fractured, brecciated and intensely silicified feldspar-phyric granite intruded by dykes of banded porphyry (Granite II of the Mount Pleasant Granitic Suite).

Stop 11: Mount Pleasant Fire Tower Zone

Return to the vehicles at Stop 10 and continue along the bush road. At 300 m from Stop 10, turn right at the T-intersection. Continue along for 1 km and bear right at the Y-intersection and continue for another 0.2 km and park. Walk south along the road and up the hill, past the sharp turn, to the outcrops southeast of the communications tower (approximately 400 m).

11A: Fire Tower Breccia. Early silicified breccia is intruded here (Fig. 26) by banded porphyry dykes (Fig. 38a) that likely were derived from Granite II. The breccia consists of bluish grey to white, greisen-altered fragments that are angular to subrounded and typically 1 cm to 10 cm in size. The fragment protoliths are mostly unknown because the original textures have been obscured by alteration, but locally quartz–feldspar porphyry can be recognized. The dyke rocks are greenish black, sparsely porphyritic (quartz + feldspar <5% and generally

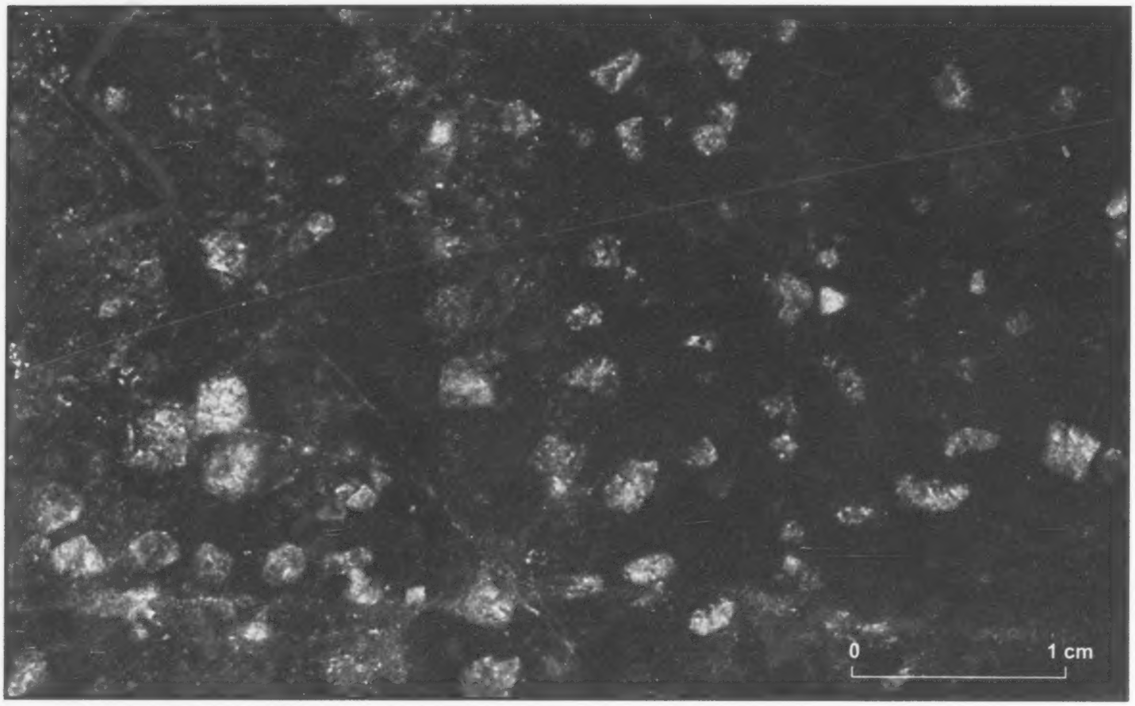

Figure 37a. Massive porphyritic rhyolite of the Little Mount Pleasant Formation at Stop 10A.

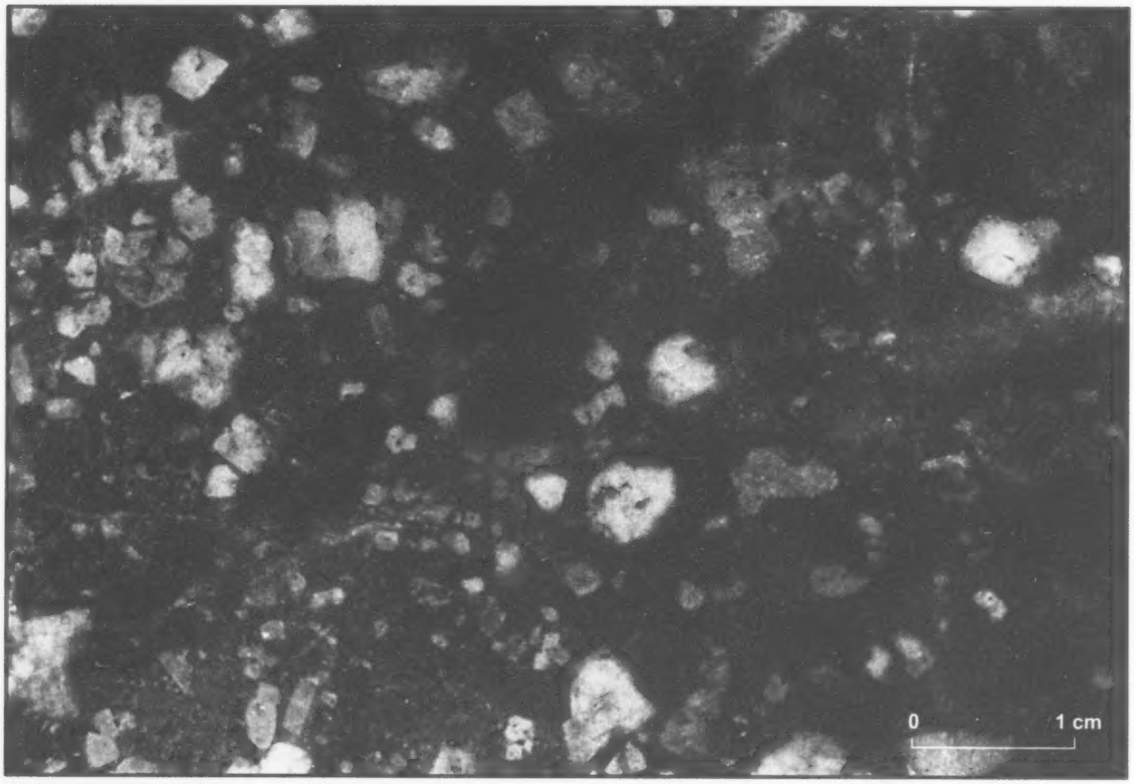

Figure 37b. Feldspar porphyry (MBG1) of the McDougall Brook Granitic Suite at Stop 10B.

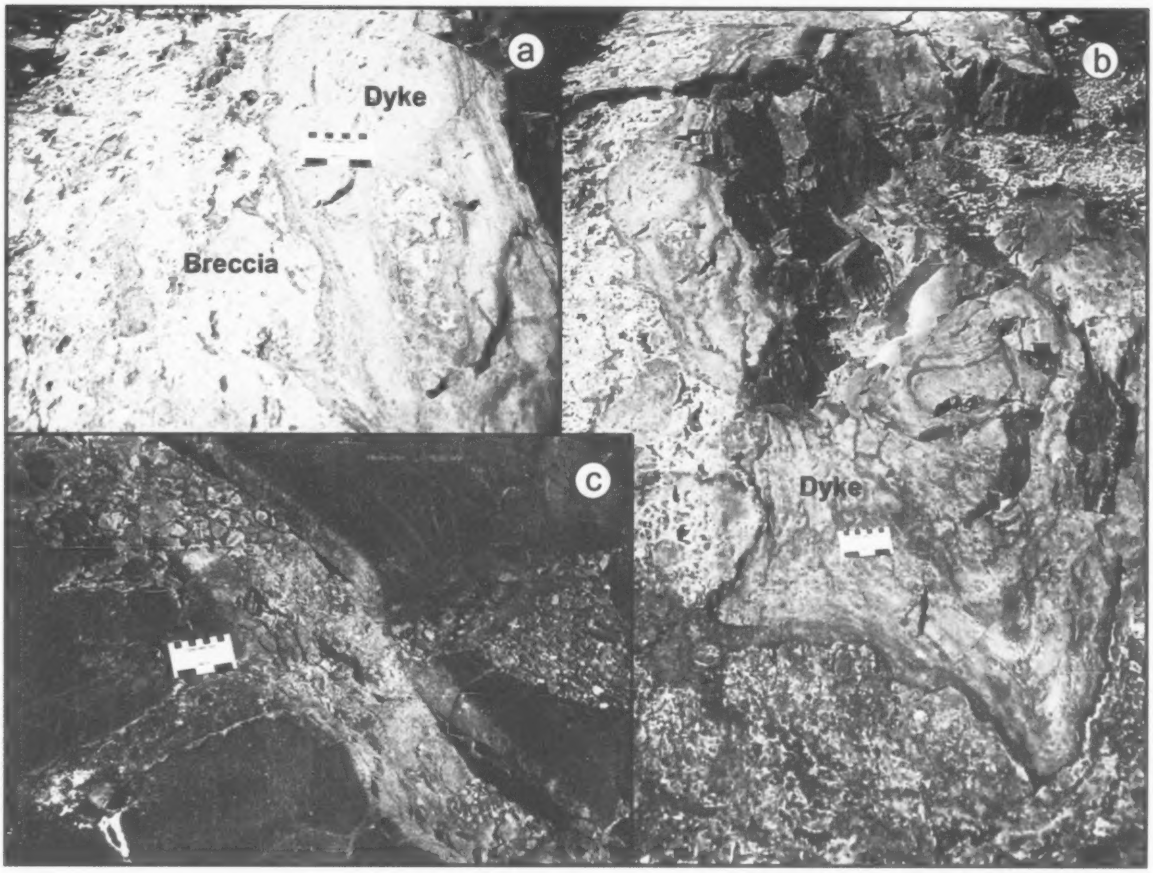

Figure 38. Rocks of the Mount Pleasant Granitic Suite (Granite II) at Stop 11A. a) Early silicified breccia intruded by banded porphyry dykes. b) Closer view of the greenish black dyke rocks with cryptocrystalline groundmass. c) Cross-cutting relationship between the dykes. Scales are in centimetres.

<1 mm), and have a cryptocrystalline groundmass (Fig. 38b). Near the contacts, the dykes contain xenoliths of country rock and exhibit well-developed flow layering. Cross-cutting relationships between dykes indicate multiple stages of intrusion (Fig. 38c).

Bear left past the communications tower along the path through the trees and to the large open area (approximately 200 m).

11B: Mount Pleasant Granitic Suite (Granite II). A plug of greyish green, porphyritic granite underlies most of the open area (Fig. 26). Phenocrysts are more abundant in the granite than in the banded dykes, but they generally constitute <10% of the rock with subequal amounts of quartz and feldspar (up to 2.5 mm). The granite groundmass is microcrystalline rather than cryptocrystalline. Yellowish grey silicified zones cut the granite plug, being localized along, and dissipated outward from, fractures. A few pebble dykes up to 1 m wide but mostly <30 cm wide also cut the granite plug. Most of the clasts in the pebble dykes are porphyritic granite, but some are also bluish grey, greisenized feldspar porphyry.

Follow the trail to the north out of the cleared area and down over the hill to the large trench (approximately 200 m).

11C: Mineralized Fire Tower Breccia. *Fluorite, molybdenite, and wolframite occur in fractures and quartz veinlets in silicified felsic breccia of Granite I exposed in the large trench east of the drill road. A dyke of banded porphyry of Granite II that locally contains comb quartz layers intrudes this breccia. A pit in the breccia a few metres west of the drill road contains an indium-bearing, sulphide-rich vein.*

Stop 12: 900 Adit

Proceed east along the road back to the vehicles at Stop 11 (approximately 150 m). Turn around and drive back the way you came. At 400 m from Stop 11 in the hollow is an intersection with a bush road on the left (west) side. Park and walk 240 m west along the bush road to the site of the 900 adit and dump.

Rock of the Mount Pleasant Granitic Suite is exposed in the road on the east side of the adit (Fig. 26). Fractured and altered porphyritic rhyolite of the Little Mount Pleasant Formation occurs on the west side of the adit. The adit was developed to explore a small replacement body of tin-bearing sulphide mineralization (the # 7 Tin Lode). Samples of massive sulphides including sphalerite, galena, chalcopyrite, cassiterite, and stannite may be found in the dump on the north side of the road. Roquesite ($CuInS_2$) has been identified in polished sections of samples from this area.

Stop 13: Endogranitic Subzone

Return to the vehicles and drive back to the north gate (2.9 km). Proceed through the gate and turn left, making sure that occupants of the last vehicle close and lock the gate behind them. Turn right at the road to the mine office. Stop 13 is 300 m farther along, in the road.

Cassiterite-bearing samples obtained from the subsurface Endogranitic Subzone (Fig. 27) occur in the parking lot to the south of the main gate at the mine site (Fig. 26). Metasedimentary rocks of the Silurian Sand Brook Formation (Fig. 26), which formed the walls of the Mount Pleasant Caldera Complex, are exposed in several places around the mine site.

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ISBN 978-1-55471-026-3

Price: $25.00